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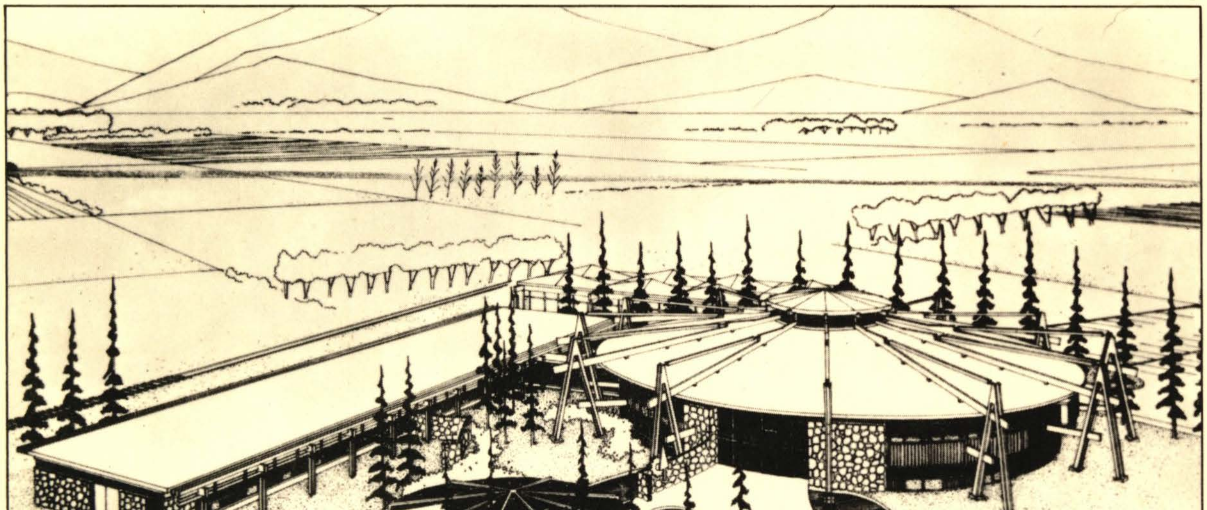

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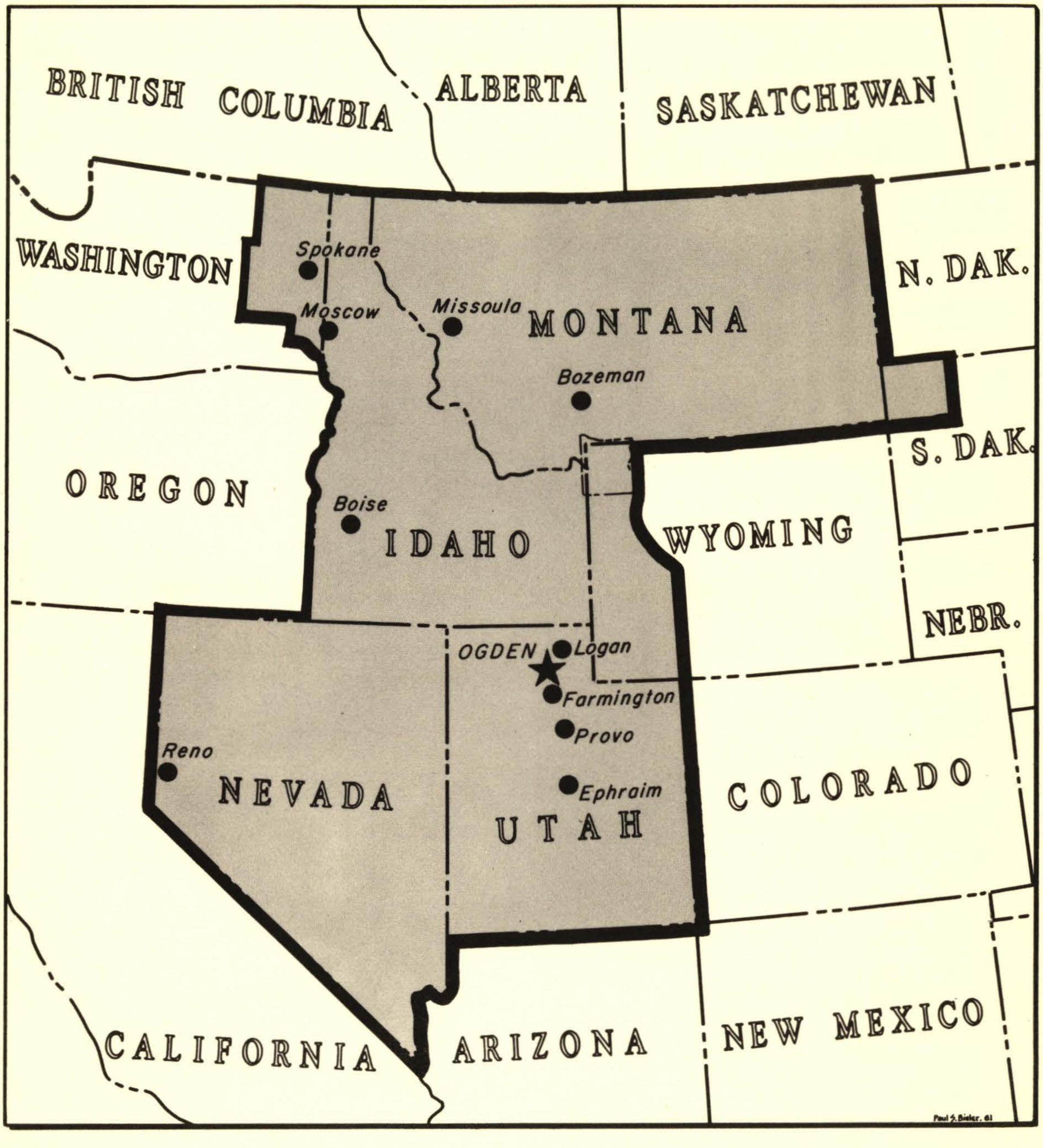
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Cover Photo: Architect's sketch of Intermountain Station's unit at Bozeman, Montana.

FOREST MANAGEMENT RESEARCH

During 1961 the program of forest management research was reorganized into five major projects as follows:

Silviculture of western white pine and associated species, including tree improvement and seed orchard management (Spokane, Washington, and Moscow, Idaho.)

Silviculture of ponderosa pine and interior Douglas-fir in the Northern Rocky Mountain and Intermountain regions (Boise, Idaho).

Silviculture of western larch and Engelmann spruce (Missoula, Montana).

Silviculture of lodgepole pine in the Northern Rocky Mountain and Intermountain regions (Bozeman, Montana).

Mensuration studies of timber types and species in the Northern Rocky Mountain and Intermountain regions (Spokane, Washington).

We have well qualified leaders for each of these projects and additional capable scientists on most of them. The white pine silviculture project has five scientists including the project leader; the ponderosa pine project, two; western larch, three; lodgepole pine, two; and mensuration project, one. We do not have sufficient staff now to begin research on either Engelmann spruce or interior Douglas-fir types.

SILVICULTURE OF WESTERN WHITE PINE

The year 1961 marked 50 years of organized forest management research by the U.S. Forest Service in western white pine forests. During these years much has been learned: about silvics of the species making up these forests; about harvest cutting systems to regenerate the forests successfully; about methods for seeding and planting; about growth, mortality, and yield to be expected; about natural development of the forests from seedfall to maturity; about cultural methods to improve the timber crop; about silvicultural methods for coping with insects and diseases; and about tree improvement through applied genetics.

This knowledge, gained by organized research and management experience, forms the basis for present management of western white pine forests, but it frequently is too general to meet the needs of management that is constantly becoming more intensive. So our quest for more precise knowledge in almost all fields of forest management continues.

Our present program of research in western white pine forests is centered mainly on artificial regeneration, tree improvement by genetic and cultural means, stand improvement by cultural means, and studies of growth and yield. Following are examples of studies in this program.

Tree Improvement

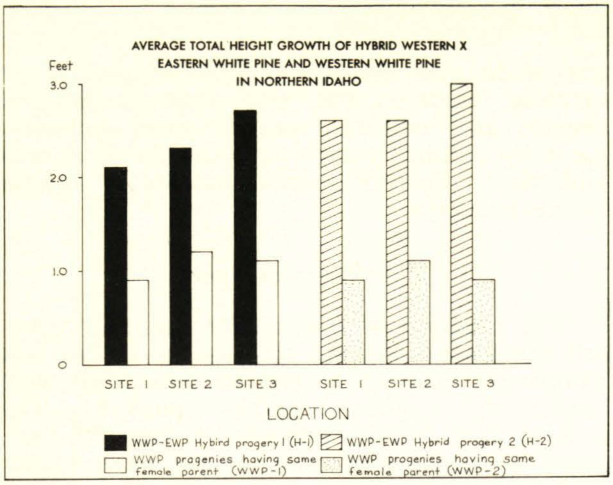
The program of tree improvement in western white pine, located at Moscow, Idaho, is a companion program to the western white pine blister rust resistance project (page 8). The goal of this forest management research program is to improve traits other than blister rust resistance—particularly vigor and timber quality. Hybridization, selection and breeding, and studies in natural variation are three avenues to improvement being explored.

Interspecific Hybridization

Hybrids between western and eastern white pine grow well both in the nursery and in the forest. The accompanying graph depicts height growth at three locations in northern Idaho of two 8-year-old progenies of the hybrid compared with western white pine progenies having the same female parent. At each location the average height growth of the hybrid progenies was at least twice that of western white pine progenies. These progenies will be observed periodically to determine whether superior hybrid performance continues as the trees mature. Since the hybrids have grown so well, we plan a more extensive progeny test using selected parents.

Selection and Breeding

Before designing a program of selection and breeding for the two traits, vigor and quality, the amount of genetic and environmental control over these traits—heritability—should be determined. Heritability values indicate the genetic proportion of variation of a trait *only under conditions of the experiment.* Data for recent analyses were taken from planted western white pine seedlings 10 years old that have grown for 6 years under essentially a forest plantation environment. Results of analyses of heritability reveal that the amount of genetic control on height and diameter growth of these young pines is low. Also, progenies did not perform consistently at different sites or in different blocks at a given site. Such a genotype-environment interaction would greatly affect the design of a breeding program, and thus its nature and magnitude will be studied in greater detail in continuing studies of genetic and environmental components of variation.



Natural Variation

We started a study of natural variation in western white pine in 1961 because (1) the environmental proportion of variation in growth attributes is quite high and (2) because not all genotypes react in the same way when subjected to different environments (genotype-environment interaction). Clearly we need more and better understanding of various separate factors of the environment—elevation, aspect, climate, etc. — that greatly influence tree growth. Throughout the range of western white pine, elevation is a frequent and important source of variation. The purpose of this new study is to determine from parent trees and their progeny the nature and extent of morphological and physiological differences that are associated with elevation.

One practical outcome would be the determination of elevational zones for seed collection and planting. To accomplish this objective, one drainage in northern Idaho was selected where natural stands of white pine could be sampled from 2,500 to 5,200 feet along one aspect. At elevations of 2,500, 3,000, 3,500, 4,000 4,600 and 5,200 feet three plots containing eight trees each were established. Cones and needles were collected from each tree and stem and branch measurements were made in the upper crown. Subsequently seeds and seedlings will be tested to determine the correlation between morphological and physiological traits and elevation of the seed source.

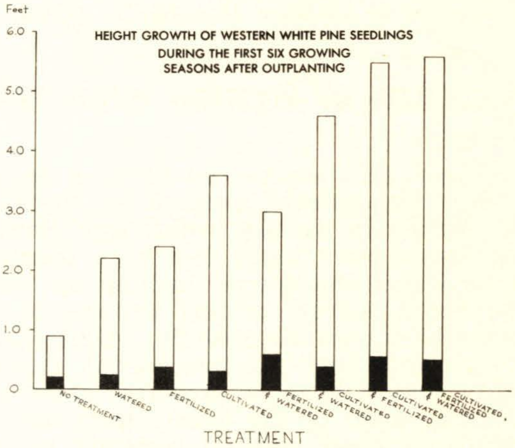
Effects of Cultivation, Water, and Fertilizer

Seed orchard technology is another phase of the western white pine improvement program. In 1955 we began an experiment to determine the effectiveness of cultivating, fertilizing, and watering, singly and in all possible combinations, upon flower induction and growth rate of seedling pines. In the station's Annual Report for 1957 the effect of these treatments upon height growth during the 1957 season was discussed (pp. 12-13). The graph below illustrates the height growth during that season and the total growth during six growing seasons (1956-1961). These data are averages of four to eight trees per treatment. Whereas fertilizing had the greatest effect of all single treatments in 1957, cultivating now appears clearly superior to the other single treatments. After six growing seasons, cultivation alone is also superior to the combined fertilizing (F) and water (W) treatment, whereas in 1957 the FW combination showed the best response in the entire experiment. Cultivating, when coupled with fertilizing, shows about the same response as the CFW treatment.

One theory now advanced to explain early flowering in woody plants is that attainment of certain physical size is responsible. If size alone is the most important factor, the treatment or combination of treatments that effects the greatest growth response would also be the most effective in promoting precocious flowering. Only one tree has flowered in the 6 years since outplanting. In 1959 and again in 1961 one tree (under CFW treatment) produced a few male strobili.

Response of Western Redcedar to Release

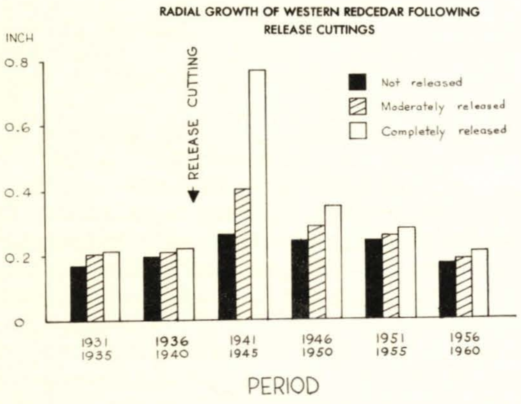
Western redcedar is a valuable species in western white pine forests, but we know little about cultural measures that might be used to stimulate its production. Studies at the Priest River Experimental Forest indicate what may be expected from release cuttings.



In 1940, an 80-year-old stand consisting of an overstory of western white pine, western larch, and Douglas-fir and an understory of western redcedar, western hemlock, and grand fir was treated in the following ways: (1) defective overstory trees were removed and the understory was thinned to favor 200 to 400 of the best redcedars per acre, and (2) about 400 redcedars per acre were completely released. Growth of the stand was studied by periodic measurement of 1/10-acre sample plots and by increment borings.

Complete release of the cedars increased growth rate during the first 5 years following cutting (see graph). Radial growth of the released cedars for this period averages 0.76 inch as compared to 0.26 inch on the control plots. However, this response was short lived. Fifteen years after liberation, the growth rate of the completely released cedars had declined to the level of the unthinned controls. Growth of the cedars in the moderately released plots has shown a similar pattern, but at a much lower level.

In 1955 we noted a general decline of crown vigor on the completely released trees. Neither the poor condition of the crowns nor the drop in growth rate following the good initial response could be explained by any visible competition factor, but a relatively high incidence of *Armillaria mellea* fruiting bodies was observed. Subsequent results of a more intensive investigation of actual fungal infection are reported below in the Forest Disease Research section of this report.


RADIAL GROWTH OF WESTERN REDCEDAR FOLLOWING RELEASE CUTTINGS

SILVICULTURE OF PONDEROSA PINE

Our program of forest management research in ponderosa pine since World War II has been diverse. We began a long-time comprehensive test on the Boise Basin Experimental Forest of two silvicultural systems — individual tree selection and group selection; we tested precommercial and commercial thinnings in the Inland Empire area and in western Montana; we studied growth and yield in young stands in the Inland Empire and in mature partially cut stands in western Montana; and we cooperated with Region 4 of the Forest Service in studies of planting in central Idaho.

Our present effort is concerned primarily with the cooperative planting studies in central Idaho—specifically studies of effective planting on steep slopes. Of course we are continuing the long-time studies also.

Soil Requirements of Trees

How much soil and what kind of soil does a tree need? Abundance of shallow-soiled areas supporting variously stocked stands in the Intermountain region has led us to caution in harvesting mature and overmature stands. Virgin stands on shallow soils are the result of tree establishment over a long period of time; they do not indicate that new stands can be established easily after cutting. Poor survival has characterized recent attempts to plant in shallow-soiled sites.

Preliminary evidence also indicates that some "natural" forest openings results from some soils being unconducive to seedling establishment. These openings, surrounded by healthy timber stands, contain ample soil in terms of depth; but measurements indicate that these soils have very low water-holding capacity. During summer drought, moisture drains through these soils faster than seedling roots grow. Trees planted in these openings have been compared with others from stock of the same origin and age planted in group clear-cuttings; the trees planted in natural openings generally survived poorly in the comparisons.

The attempt to plant trees by machine after thorough site preparation in this natural forest opening failed. Evidence indicates that low water-holding capacity of the soil was responsible for the poor survival.

Thus, we have at least two field conditions that are likely to cause low survival in forest planting; namely, shallow soils, and soils having extremely low water-holding capacity with little or no B horizon. These observations and tests have prompted us to have a soil survey of the Boise Basin Experimental Forest made so that we can judge better where to clear cut, where to plant, and what will be the likelihood of success in planting. In fact, in old-growth timber, where shallow soils predominate—soils whose depth will probably prevent acceptable survival of planted stock—we believe that there should be no clear cutting of these sites, but rather stem selection.

SILVICULTURE OF WESTERN LARCH

Forest management research in western larch during the past 15 years also has been concerned with several problems. We have studied growth in cutover mature stands; we have investigated the silvics of the species; and we have tested various natural regeneration systems on our Coram Experimental Forest and elsewhere. Our present program emphasizes cultural treatments in very young stands, artificial regeneration by seeding and planting, and effects of site and stand conditions on growth and wood properties in pole-size stands.

Stratification Reduces Delayed Germination

Spring-sown western larch seed must be stratified and sown at the proper time to insure prompt and complete germination. In three experiments conducted at the Coram Experimental Forest using nonstratified seeds, about one-third of the viable seed germinated during the first year; the remainder germinated the following spring. A more recent study showed that prompt and nearly complete germination resulted when larch seed was stratified and then sown early in May.[1]

The following tabulation shows cumulative germination at the end of the first and second growing seasons for two pretreatments and two sowing time combinations.

Pretreatment	Cumulative germination by date of sowing			
	Sown April 15, 1960		Sown May 6, 1960	
	1960	1961	1960	1961
	Percent			
Control	5	17	4	17
Hydrogen peroxide	6	7	5	9
Stratified	22	26	42	44

No seed pretreatment effected complete germination the first growing season, but stratified seed sown in May approached the total viability. Time of sowing stratified seed is important in obtaining maximum germination. Although H_2O_2 pretreatment facilitates rapid and complete germination in the laboratory, its effect apparently is harmful to seeds subjected to field conditions when temperature fluctuates widely each day.

Thinning in Juvenile Stands

Overstocked stands of western larch are common throughout the northern Rocky Mountains. Growth in these stands is being distributed among many stems rather than a few selected ones. Much growth potential of the site is being wasted in small stems, many of which will die from competition before reaching merchantable size. To grow selected trees at an optimum rate, it is necessary to thin the young stands while the trees still have full crowns and can respond well to release. But thinnings pose these questions: How heavily and how frequently should young larch stands be thinned to manage them for achieving optimum growth for any single end-product or combination of products? Since shrubs usually grow rapidly after the trees are thinned, will it be necessary later to remove the shrubs from the stand to keep them from competing as vigorously as the trees that were removed?

We began studying these problems this year in cooperation with the Flathead, Kootenai, and Lolo National Forests. Primary objectives of this study are: to learn the effects of stocking level (number of trees per acre), thinning interval (number of years between thinnings), and shrub competition on growth, form, and crown characteristics of western larch; and to develop spacing guides for use in managing young stands of western larch.

Growth of Crop Trees

Forest management planners are faced with the problem of determining technical rotations for various species and end products and projecting future yields related to forest conditions and utilization requirements. Realistic estimates require basic information concerning the potential development of crop trees under a variety of conditions found in the forest. Manufacturing plants are built or revised and forest management investments are made upon the prospects of future forest production estimated from such information.

Recently, Intermountain Station undertook a cooperative study with the J. Neils Lumber Company and the national forests of western Montana, northern Idaho, and northeastern Washington on management of western larch for production of transmission poles. This study related the growth and quality of western larch trees to tree and site factors. Although the study was aimed primarily at management of western larch for producing transmission poles, the data are useful for many other products as well. Field work of the initial study has been completed now with collection of data on 463 temporary sample plots, and analysis of the data has started. The accompanying table illustrates one type of information that has come from this study. Analysis has provided equations for predicting the average height and diameter of "crop trees" in stands now producing merchantable transmission poles.

Information in the following table shows the potential of western larch crop trees in stands within the Douglas-fir vegetational zone[2] of the northern Rocky Mountains. It enables the forest manager to select technical rotations for transmission poles or any other product of interest. Of course, more detailed analysis will provide additional information on the influence of individual tree and site factors. Further analysis will also determine similar information for western larch in other vegetational zones, as the Engelmann spruce-subalpine fir and western redcedar-western hemlock zones, where western larch occurs.

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[1] Intermountain Forest and Range Experiment Station. Annual Report, 1960, p. 3.

[2] See Daubenmire, R. 1952. Forest vegetation in northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monog. 22: 301-330.

Diameter, total height, and volume of western larch crop trees, by total age and site index.

	Site index											
	55				75				95			
Age (years)	Diam.[1] breast high	Total[2] height	Volume		Diam.[1] breast high	Total[2] height	Volume		Diam.[1] breast high	Total[2] height	Volume	
	Inches	*Feet*	*Cu.Ft.*[3]	*Bd.Ft.*[4]	*Inches*	*Feet*	*Cu.Ft.*[3]	*Bd.Ft.*[4]	*Inches*	*Feet*	*Cu.Ft.*[3]	*Bd.Ft.*[1]
20												
40	6.0	46	2.20	....	7.4	58	5.01	....	9.0	85	11.77	....
60	8.6	65	8.08	....	10.8	84	17.24	71	13.0	110	32.72	154
80	10.8	79	16.22	66	13.8	103	34.52	162	16.7	135	64.76	342
100	12.8	91	26.24	117	16.5	118	55.58	288	20.0	152	100.32	566
120	14.8	101	38.72	189	19.0	130	78.84	434	23.3	167	154.13	911
140	16.4	108	50.25	256	21.5	140	104.19	607				
160	18.5	116	66.90	358								
180	20.5	123	84.51	483								

[1] D.b.h. prediction based on 10-year growth curve with the following equqation:
10-yr. d.b.h. growth $= 35.8398 \left(\frac{1}{\text{age}}\right) + 0.01572$ (site index) $- 0.36494$ SE $= 0.677$ R $= 0.939$ n $= 337$

[2] Height prediction based upon the following equation:
Total height $= 53.50861 - 1.49444$ (site index) $+ 0.80717$ (age) $- 0.00090$ (age)^2 $- 54.83279$ (log d.b.h.) $+ 2.16890$ (site index) (log d.b.h.) $- 0.21541$ (age) (log d.b.h.) S.E. $= 7.16$ R $= 0.939$ n $= 1073$

[3] The cubic volume shown is the peeled volume between a 1-foot stump and a 4-inch inside bark top.

[4] Scribner board-foot volume.

Ultimately the analysis will provide information on the relation of such factors as stand age, tree vigor, elevation, aspect, slope, level of stocking, and ecological habitat type to tree diameter, height, volume, sapwood depth, specific gravity spirality, and pole size and class.

Tree Vigor Classification

A quick, easy method for examining tree vigor is a useful aid to foresters when planning cuttings, stand improvement, or other management practices in western larch stands. In 1948[3] this station prepared a preliminary vigor classification for trees in the western larch—Douglas-fir type in Montana. Collection of data on western larch pole management throughout western Montana, northern Idaho, and northeastern Washington since then has provided an opportunity to check the effectiveness of this vigor classification over a substantial portion of the range of western larch. A specimen tree on each of 363 plots, which was a crop tree containing a merchantable pole, was measured in great detail and its vigor was classified on the scale shown below. The vigor estimates were made by as many as seven or eight persons. Ages of trees included in the study ranged from 30 to 160 years, and crown length ratios varied from 10 to 90 percent of total tree height. When the data were first arrayed it appeared that the bulk of the difference in diameter growth at breast height was associated with total age and crown length ratio. A multiple covariance analysis was used to remove the variance due to these two variables and test the adjusted means. Actual and adjusted means are shown below:

Vigor class	Actual mean diameter growth at breast height	Adjusted growth means
	- - - - *Inches*	- - - -
A (good vigor)	1.555	1.282
B (medium vigor)	.870	.914
C (poor vigor)	.515	.712
Total	.960	

F value for 2/358 d.f. = 28.37, showing a highly significant difference in adjusted means.

Analysis showed that: (1) factors in the classification other than age and crown length ratio are important in classifying tree vigor; (2) age and crown length ratio are highly significant variables; and (3) site index when included as an adjustment variable was nonsignificant; hence the classification is independent of site quality. These results verify the tentative classification developed in 1948.

SILVICULTURE OF LODGEPOLE PINE

Our lodgepole pine project is concerned at present primarily with two major problems: how to regenerate certain problem cutting areas on the Gallatin and Targhee National Forests in the vicinity of Yellowstone National Park, and to determine the effect of stand density on growth, yield, and site quality evaluation. We have also begun a study of site evaluation in cooperation with other western Forest Service experiment stations.

Survey of Serotinous Cones and Availability of Seed

In July 1960, one of the largest timber sales in the history of the Forest Service was made on the Targhee National Forest. It involved 318 million board feet of timber on the Moose Creek Plateau near Ashton, Idaho. Previous cuttings nearby had been followed by some regeneration difficulties. Some areas have either failed completely to regenerate by natural means or will need considerable interplanting to bring stocking up to a desirable level. Although exact causes of failure of regeneration here are not known, these failures indicate possible difficulty in effecting natural reproduction within the new sale area and on a similar problem area near West Yellowstone, Montana.

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[3] See Roe, Arthur L. 1948. A preliminary classification of tree vigor for western larch and Douglas-fir trees in western Montana. North Rocky Mountain Forest and Range Expt. Sta. Res. Note 66. 6 pp.

Lodgepole pine generally regenerates successfully by natural means if sufficient quantities of seed reach bare mineral soil. Present practices for regenerating this species generally rely upon the presence of seed stored in closed cones in the slash following logging operations. This method has been successful in central Montana where serotinous cones are abundant. Thus, along with other phases of the reproduction problem, it is important to know first whether lodgepole pine within a given area is of the closed-cone type and to what extent serotinous cones can be relied upon for natural regeneration.

Cone sample from a single lodgepole pine branch. Twenty-five 1-foot samples are taken from each tree.

During the 1961 field season we started a survey of serotinous cones on the problem areas in Idaho and Montana. After completing this survey we plan to sample cones stored in the slash on areas that have been clear cut recently to estimate the amount of seed stored in the slash.

Seedbed Preparation for Regeneration

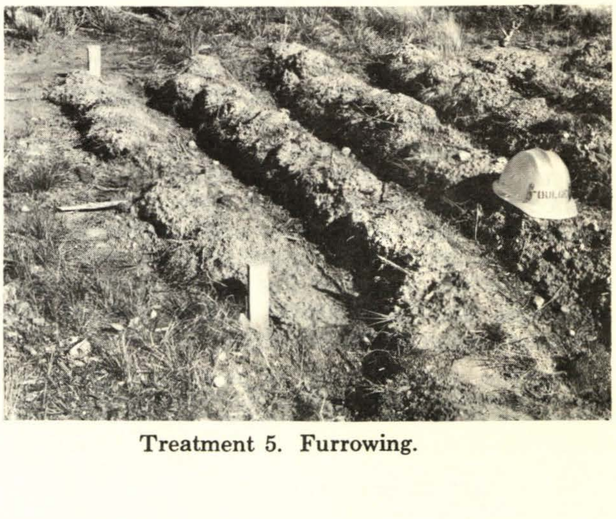
Seedbed preparation is important in regenerating lodgepole pine. The area to be regenerated is usually scarified to expose mineral soil and to reduce the amount of competing vegetation. Difficulties of regeneration in stands between Ashton, Idaho, and West Yellowstone, Montana, have raised several questions. Are grasses and sedges that are abundant here a prime factor in germination losses? Are special treatments needed to conserve existing soil moisture and provide protection for first-year seedlings? What method of seedbed preparation will provide optimum conditions for germination and survival?

To obtain answers to these questions we installed a study in three areas on the Targhee and Gallatin National Forests this year. We are testing nine methods of seedbed preparation on a series of 2-milacre plots in three different physiographic zones: (1) Big Springs Flat, (2) Moose Creek Plateau, and (3) West Yellowstone Flat. Seedbed treatments are:

1. *Control.* Natural undisturbed duff.
2. *Burning.* Burning with no attempt to expose mineral soil.
3. *Scalping.* Stripping off all vegetation.
4. *Scalping and cultivating.* Stripping off all vegetation and cultivating to a depth of 6 inches.
5. *Furrowing.* Trenching 3 to 4 inches deep; soil is thrown to one side leaving a sharp perpendicular edge to the south to provide shade.
6. *Trenching.* Trenching 3 to 4 inches deep; V-shaped trenches have a 45° angle to both north and south and thus provide no shade.
7. *Simulated "Fleco" trenching.* Partial scalping followed by trenching; trenches 1 to 3 inches deep and about 16 inches apart.
8. *Scalping, cultivating, and spraying.* Treatment 4 followed by spraying with Dalapon at recommended rate per acre.
9. *Disking.* Disking with a lightweight disk harrow.

Wood Specific Gravity

Preliminary results from a study of specific gravity of lodgepole pine in the Intermountain region are now available. In 1960 we extracted increment cores and collected stem sections from felled trees on several forests in Utah, Idaho, and Wyoming. This work was one phase of a major study of specific gravity relations for western softwoods started by the Forest Products Laboratory at Madison, Wisconsin. We found that specific gravity at breast height as determined from increment cores gave a valid estimate of average tree specific gravity for the lodgepole pines in the study.



Treatment 5. Furrowing.

Treatment 6. Trenching.

MENSURATION

Studies of tree and stand volume, growth, mortality, and yield have always occupied an important place in forest management research at Intermountain Station. As a result, we have developed mensuration tools for some of our tree species and forest types. However, as timber management becomes more intensive, some of these tools are not good enough; and we are completely lacking in mensuration information for other tree species and forest types. Therefore, during 1961 we organized a mensuration project whose objective is to study the broad mensurational problems of forest tree species growing in the Northern Rocky Mountain and Intermountain regions including (1) the influence of species composition, natural and modified stand condition, and site on growth, yield, and quality of forest products; (2) the development of improved methods for predicting growth and yield to facilitate preparation of cutting budgets; and (3) the development of new or improved methods of inventorying forests and estimating volume of trees and tree products.

The mensuration project is fully occupied now with a study of volume, growth, yield, and site quality of grand fir. Field work has been completed, data have been compiled, and analysis and report writing are in progress.

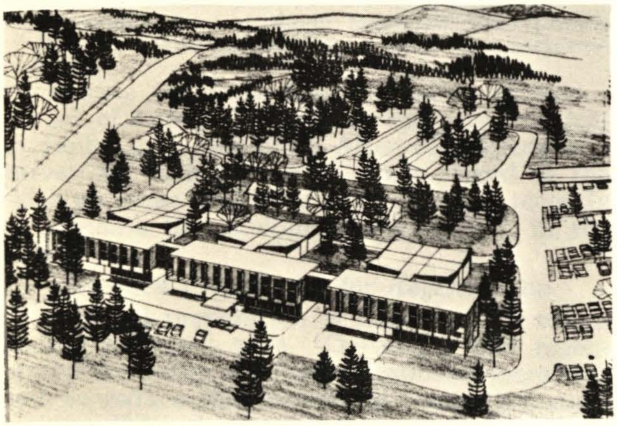
FOREST DISEASE RESEARCH

A landmark for this year was approval for construction of a second office-laboratory unit at Moscow, Idaho, to house research in forest diseases, forest insects, forest management, and watershed management. The building site is at the east edge of the University of Idaho campus and adjoins the Station's office-laboratory that now houses our forest genetics activity. Designs for the new building were completed and the first stage of construction has been scheduled for 1962. Temporarily the first section (disease) will be shared with project men in forest management and watershed management research; but eventually they will have a separate unit, as will forest insect research.

WHITE PINE BLISTER RUST PROJECTS

Accelerated Breeding Program

The momentous event of 1961 in this program was collection of the first thimbleful of second-generation seed from blister rust-resistant parent trees. The parent trees were selected F_1 seedling that had been transplanted into our breeding arboretum at Moscow; they were only 9 years old from seed. This production of seed emphasizes the fact that attainment of the practical short-range objectives of our breeding program is imminent. Foremost of these objectives is mass production of second generation seed with a useful, if partial, level of rust resistance, beginning with establishment of seed orchards, possibly within a decade.[4]



Intermountain Station's office-laboratory unit will be built at Moscow, Idaho, on a site provided by the the University of Idaho. When completed it will house research in forest diseases, forest insects, forest management, and watershed management.

Now that practical objectives of the tree breeding program are in sight, we are greatly accelerating the routine work in selection, breeding, and progeny testing. Seasonal work schedules under this accelerated program are complex. Activity centers at Moscow, but fans out in a 150-mile radius over a semicircle to the north, east, and south. First generation crossing is done on "wild" trees selected in the woods. Then progenies from these crossings are tested at the genetics center.

During 3 summer months, a crew of 4 to 6 men traveled more than 12,000 miles, largely on forest road, in carrying out tree-breeding work. They extracted and collected pollens from more than 100 trees and used them in making 280 controlled pollinations on 65 trees. This required tying some 2,200 pollination bags on the topmost branches of these trees—which average 75 feet in height; also tying another 1,500 cloth bags in treetops to protect immature cones that had developed from pollinations made in 1960.

Several important technical improvements have increased efficiency in this work, among them: (1) standardized test-crossing to appraise each new tree selection, (2) presowing seed lots on paper strips to simplify nursery planting, and (3) use of very large single-piece polyethylene-film inoculation chambers for large-scale artificial inoculations.

During the year we inspected 125 new canker-free resistant parent trees on three national forests: 47 on the Clearwater, 54 on the St. Joe, and 24 on the Kaniksu. Location of these trees brings our total of "wild" resistant trees to 347—just 53 short of our goals of 400. Previous tests of first-generation test-cross progenies indicate that about 80 to 100 of the 400 trees will prove to be good transmitters of blister rust resistance. Ulitmately they will provide the germ plasm for stock for our seed orchards.

Interspecies Hybridization

The long-range program for introduction of new and different resistance genes from exotic species continues. Putative hybrid seed obtained from 14 to 25 interspecies pollinations attempted in 1960 were sown in progeny tests in 1961. Also, this year we attempted another 28 interspecies pollinations. Six important European and Asiatic white pine species and four American species exhibited more overall resistance than western white pine. Hybridization, i.e., crossing western white pine with these ten species, will continue until as many hybrids as possible from the ten exotic species have been obtained. After selection for local climatic adaptation, these hybrids will be held until needed as a pool of possible new resistance genes.

Seed Orchard Technology

Mass production of pedigreed seed in

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[4] For further details of breeding results and plans for seed orchards, see *Highlights in Research,* Annual Report for 1960, pp. 9-10.

grafted seed orchards apparently can be hastened by field grafting on vigorous stock plants preestablished at proper spacing on the proposed seed orchard sites. We have started grafting trials to explore this possibility.

In early March we collected scionwood from 10 different 15- to 20-year-old white pines in two natural stands near Clarkia, Idaho. By mid-March 100 "whip-and-tongue" grafts had been made, matching cuts on 1960 wood of the branch-terminal scions with those on 1960 wood of stock plant stems. Stock plants represented more than 30 different open-pollinated seedling lots, each lot from an individual parent tree.

By mid-October only 9 grafts had failed. Although 12 other stock plants had died, all effected good graft union and scion growth prior to death. Thus, about 90 percent of the grafts were successful—the best rate of success in any of our greenhouse grafting work. Furthermore, scion growth for the 1961 season averaged 4 inches, far more than for any previous year. The entire 100-graft experiment will be repeated in 1962; and it will be enlarged to include studies aimed at determining range of dates for satisfactory early spring grafting, necessity for waxing the area of the graft cuts, and the feasibility of using a simpler and less expensive cleft graft.

Biochemistry of Rust Resistance

Biochemical analyses of blister rust-resistant and susceptible western white pine have shown that many physiologically important compounds vary qualitatively and quantitatively with season of year, tissue (bark or needle), growing conditions, and degree of infection by the disease.

Several groups of compounds examined to date have not been found to be associated with blister rust resistance: free sugars, amino acids, protein hydrolysates, organic acids, chlorophylls a and b, B-carotene, and phosphorylated compounds. Dry matter content, pH, and ash weight were also measured, but yielded no clues to what causes resistance. The study of phenols and polyphenolic substances now under way will complete one phase of this project. Bioassay and serology tests are contemplated for the next phase.

Resistance Through Induced Mutations

The mutagenic agent ethyl-methyl-sulfonate has been tested on western white pine seed to determine optimum concentrations and soaking times. This chemical showed definite effect on seed germinability in replicated trials. Germinability of tested seed varied from 16 to 95 percent on untreated seeds. An extensive study now under way uses three treatment levels on seed from partial diallel crosses. Along with possible changes in blister rust resistance, we are studying effects on germinability, rate of germination, number of cotyledons developed, hypocotyl length, seedling mortality, and chromosome abnormalities.

Microclimate Studies in the Inland Empire

Earlier reports have shown that certain climatic features (daily temperature range and daily precipitation values) for the months of April through October either promote or inhibit intensification and spread of western white pine blister rust. Information showing relative chances of occurrence of weather factors either favorable or unfavorable to blister rust would greatly help administrators of the rust control program in selecting areas to be protected. Climatic information collected at numerous weather stations in and near the white pine belt for many years could be used to determine probabilities of occurrence of weather factors that influence rust if it were appropriately sorted and analyzed. But the great volume of these data makes extensive analysis by hand computation difficult.

Since 1948, practically all the weather data collected by the U.S. Weather Bureau in the western white pine area have been and are currently being recorded on punched cards. Universities in each state are cooperating in a program to back-punch data for years prior to 1948 as requirements for use develop. Most of the weather stations in the Inland Empire whose data have been back-punched have been in agricultural areas. To provide data for machine analysis from stations in and near forested areas, the Intermountain Station is financing the back-punching of climatic data from 19 weather stations by Weather Bureau cooperators. Daily maximum and minimum temperatures and daily precipitation values for the months of April through October are being punched. Data from 10 other stations have already been punched. These data will be analyzed by computer.

We also need information on how variation of topography and vegetative cover influence the variation of weather factors that control the intensification and spread of the white pine blister rust. Records of temperature and humidity collected at 253 stations under a variety of conditions during the last five summers are being transferred to punched cards for machine analysis.

WHITE PINE POLE BLIGHT

The pole blight disease is a major difficulty in management of western white pine. Studies by Leaphart and Copeland indicated probabilities of varying degrees of pole blight losses on sites having different soil moisture characteristics.

Recently we completed a study of 70,000 annual rings from 340 healthy trees in 25 stands. This examination showed that the depression in growth resulting from drought in the late 1930's was the most severe in magnitude and duration experienced in the last 300 years. Good correlation between tree growth in nearby stands and the continuous weather records available from 1911 for the Priest River Experimental Forest supports the hypothesis that previous droughts of similar magnitude have not been experienced by even our oldest timber stands.

ROOT ROTS

Damage in Redcedar Release Study Plots

Examination and removal of western redcedar trees released in 1940 on study plots at the Priest River Experimental Forest (see FMR section, pp. 2-3) revealed that approximately half of the major roots of 48 sample trees contained advanced decay, whereas only 14 percent of major roots on a like number of nonreleased trees contained rot. The nonreleased trees were much less decayed than the released trees. *Armillaria mellea* was isolated from roots of nearly half of the released trees but from only 15 percent of the nonreleased trees. In September 1960, a year that was generally favorable for sporulation of *A. mellea,* we found sporophores at bases of 39 percent of the trees on released plots, 9 percent on moderately released plots, but none on control plots. Other unidentified wood-rotting organisms were isolated—on about twice as many released trees as control trees.

Initial response to release had been very favorable; but after about 10 years, growth was sharply reduced. Crowns became thin and chlorotic. Many trees showed resinosis for several feet up their stems. Dead bole area at the ground line could be located by drumming on the bark, and root systems of released trees became much more extensive than those on control trees. A few released trees showed no signs of fungal infection despite their general decline in vigor; hence, environmental factors appear to have influenced both decline and disease.

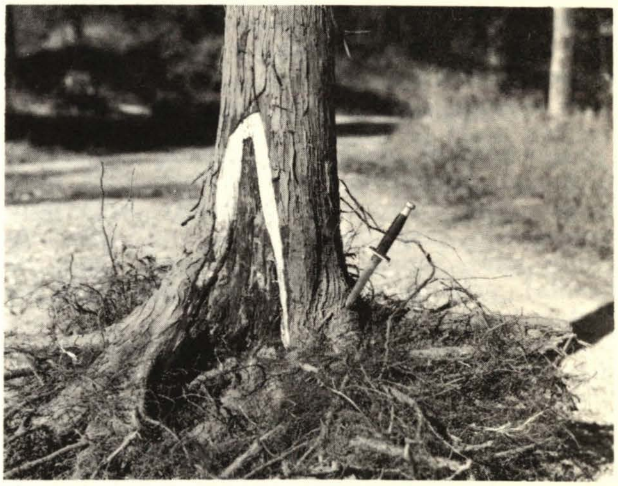
OTHER DISEASES

Dwarfmistletoes

Field and greenhouse observations of western larch infected with dwarfmistletoe reveal that spring growth, following the dormant period, begins in the infected branches of the tree 8 to 14 days prior to beginning of growth in noninfected branches. This indicates the functioning of growth regulators.

We are collecting two fungal hyperparasites on dwarfmistletoes in this area to study their morphology and sequence of development. We shall try to culture these fungi in order to study their possibility for use in biological control. *Wallrothiella arceuthobii* has been observed on Douglas-fir, dwarfmistletoe in the Moscow Mountains in Idaho and on lodgepole pine dwarfmistletoe near Kettle Falls, Washington. This fungus attacks only female plants of the parasite and prevents maturation of their seed. *Septogloem gillii* has been observed to attack both forms of western dwarfmistletoe on true firs and hemlock in the Cascade Mountains near White Pass, Washington.

This western redcedar tree shows no superficial evidence of basal attack by *Armillaria mellea.*



Same tree; but removal of bark shows infection by *Armillaria mellea.*

Seedling Susceptibility. — A western larch seedling 4 months old was successfully inoculated with dwarfmistletoe seed. The dwarfmistletoe produced aerial shoots when the seedling was only 14 months old, and had killed it by the time it was 17 months old. This indicates the susceptibility of seedlings and tissues less than a year old, the rapid development of the parasite under favorable growing conditions, and its lethal effect on such seedlings.

Storage of Seeds. — Dwarfmistletoe seeds do not remain viable when stored under conditions comparable to those used for tree seed storage. Moisture or high humidity in storage promotes molds, apparently because the seed's gelatinous sheath is highly hygroscopic.

High temperatures during storage also destroy viability of dwarfmistletoe seeds. Molding during storage was reduced by first sterilizing the seeds' surface with alcohol or acids, or by removing their gelatinous sheath with Pectinase and Hemicellulase. Douglas-fir dwarfmistletoe seeds stored in the laboratory under dry conditions at 5° C. germinated readily after 3 months and produced radicles on Douglas-fir seedlings. Seeds stored in the field in sausage casing bags remained viable and germinated well the following spring.

A red pine (*Pinus resinosa* Ait.) planted at the Priest River Experimental Forest has become infected with larch dwarfmistletoe, probably by seed dispersed from a nearby stand of heavily infected western larch. This is the first known occurrence of larch dwarfmistletoe on red pine.

Effects of Dwarfmistletoe on Growth

During surveys of dwarfmistletoe on the Colville and Nezperce National Forests we took numerous increment cores from infected Douglas-fir and western larch sawtimber trees. Ordinarily two cores were taken from opposite sides of each tree; the past 10 years' growth was measured on each core, and measurements of the two cores were averaged to determine effects of different intensities of infection on recent diameter increment. When growth of the two cores showed considerable difference, an additional core was taken and used along with the original core that was the more nearly comparable in growth.

Only trees free from abnormalities and damage other than dwarfmistletoe were sampled. Trees that appeared to have had a drastic change in competition sometime in the past were not sampled. Trees 11 to 16 inches d.b.h. were called "small sawtimber" and those larger than 16 inches were classed as "large sawtimber."

Dwarfmistletoe infection classes were determined as follows: live crown was divided into halves; infection in each half was estimated and rated numerically as (0) no infection, (1) fewer than one-third of branches having brooms or plants, (2) more than one-third of branches having brooms or plants. These numerical ratings were added to classify the entire tree on a scale of 0 to 4. Trees classified as 1 or 2 were called "lightly infected"; those classified as 3 or 4 were called moderately and heavily infected, respectively. Infection classes were distributed as follows:

Tree species and size class	Number of trees	Infection class			
		None	Light	Moderate	Hvy.
		Ratio of past diameter growth			
Douglas-fir:					
Small sawtimber	205	1.0	0.77	0.54	0.44
Large sawtimber	114	1.0	.90	.79	.36
Western larch:					
Small sawtimber	113	1.0	1.01	.73	.53
Large sawtimber	59	1.0	1.11	.81	.51

Although these results are based on only a small number of trees under a wide range of conditions, the following conclusions can be drawn:

- Light infection had no effect on recent diameter growth of western larch, a slight effect on growth of Douglas-fir large sawtimber, and a moderate effect on growth of Douglas-fir small sawtimber.
- Heavy infection materially reduced recent diameter growth of the host tree. This reduction was more pronounced in Douglas-fir than in western larch.
- Dwarfmistletoe reduced recent diameter growth of heavily infected small sawtimber less than that of heavily infected large sawtimber. In lightly and moderately infected trees the reverse was true.

Physiological Diseases

Several foresters in the Priest River region inquired last year about a disease in ponderosa pine plantations characterized by needle mortality progressing from the bottom to the top of the crown. Dead needles persisted and turned ashen gray, and growth had usually been reduced over a period of years. Investigation showed that affected trees were growing on soil underlain with hardpan, which limited vertical root development. During the past several years of subnormal precipitation, the limited root system presumably could not supply sufficient water to meet the trees' needs. Normal trees are growing in the same plantations, but the hardpan is either absent or at a depth greater than under the diseased trees.

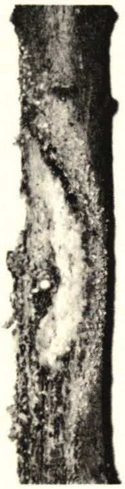
Heat injury killed 1-0 white pine seedlings at both Savenac and Coeur d'Alene Forest Service nurseries following record high temperatures in early August. Mortality was generally light and scattered. Western larch at Coeur d'Alene exhibited drought symptoms; damage seemed to be precipitated by an unfavorable root-to-top ratio.

Heat killed the needle tips of ponderosa pine and white pine shade trees in the Spokane area when hot weather suddenly followed an abnormally cool spring season.

STUDIES OF ANTIBIOTIC CONTROLS

A new project started this year is designed to study basic aspects of the physiological and chemical nature of antibiotic control of forest tree diseases. This project is part of the overall program of studies of diseases of western white pine and associated species that will be moved from Spokane to the new facilities in Moscow.

Preliminary experiments in use of antibiotic materials to control *Cronartium comandrae* and *Peridermium stalactiforme* of lodgepole pine by systemic action have given encouraging results. The methyl-hydrazone and semicarbazone derivatives of cycloheximide, when applied as basal stem treatments, prevented spore production and apparently killed these two fungi in aecial-bearing cankers in small trees. These antibiotic materials were applied in solutions of stove oil in the spring of 1959. Results from semicarbazone applied in 1959 could not be evaluated in 1960 because of aecial damage by cold that spring, but in 1961 results of the applications were obvious. The methylhydrazone was similarly applied in 1960, and cankers on treated trees appeared dead in 1961. Cankers on trees treated with other antibiotic materials and on check trees appeared normal and fruited in 1961. No control was evident on trees infected with other disease organisms, including three other rust fungi, when treated with these two antibiotics and other antibiotic materials.



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An aecia-bearing comandra blister rust canker on lodgepole pine. Aecia are the small whitish blisters around the area where bark has been removed by rodents.

Followup tests were started in 1961 with these promising materials as basal stem applications on larger trees and as foliar sprays on small trees. Foliar sprays as 20 percent oil emulsions were applied by hand sprayers on small trees, and by helicopter on large trees in eight 4-acre test plots. Some indication of results from these new applications is expected to be evident in the spring of 1962.

FOREST ECONOMICS RESEARCH

The central purpose of this station's research in forest economics is to help in development of guidance mechanisms necessary if wild lands are to contribute as they should to the welfare of the people. This involves understanding and measuring the capacity of the wild lands to produce, as well as understanding and expressing the need for the products of these lands. These supply and demand factors enable us to estimate the nature, cost, and justification of management measures and programs.

During 1961 the economics research division expanded and reoriented its activities in order to fulfill these responsibilities more effectively. To this end, we began a project in multiple-use economics in July, and have continued developing a program of research in the field. Several shifts in the Forest Survey program are enabling us to do a better job of providing the data base needed for managing the 146 million acres of forest and 61 million acres of commercial forest that lie in the eight Mountain States extending from Canada to Mexico.

In 1961 this division also was assigned responsibility for recreation research. This work involves much more than economics, but it provides timely opportunity to develop the better understanding of outdoor recreation opportunities and problems necessary if recreation is to be appropriately emphasized in multiple-use planning.

FOREST SURVEY

This year saw the beginning of a substantial reorientation of the Forest Survey program. No longer do we have overriding responsibility for all timber inventory activities. National forest personnel now inventory all the commercial forest land managed by the Forest Service. Their inventories cover about 67 percent of the commercial forest area of the Mountain States. In time, we expect that other public land agencies will provide progressively larger amounts of the necessary information regarding their own timber lands. This leaves us the field inventory job on lands not thus covered, and the bringing together of the data from various sources for state, regional, and national planning purposes.

The increasing effort in timber inventory by the national forests reflects the growing importance of such data for planning and programming. For some time we have recognized the need not only for more data but for better data. Our efforts over the past several years to develop timber inventory statistics that better describe management needs and better ways to collect such statistics have been in response to this need. We shall have to devote increasing attention to this subject in coming years.

Inventories

We had six survey crews in the field during the 1961 season—three each in Utah and northern Idaho. The Utah crews completed the field inventory phases of the initial Forest Survey in Utah. They surveyed all the forest land not administered by the Forest Service. In cooperation with the Division of Timber Management of Region 4, we also inventoried the Utah portion of Cache National Forest. The total commercial forest area in Utah covered by field inventory this year was about 1.2 million acres.

The other three crews made progress on the reinventory of northern Idaho. They completed plot work on all lands outside the national forests and alienated lands inside the national forest boundaries in Bonner, Boundary, Lewis, and Nez Perce Counties. This survey covered approximately 1 million acres of commercial forest land.

This year we completed compilations of area, volume, growth, and mortality on the reinventory of western Montana. By the end of next year we hope to publish reports on western Montana and the entire States of Colorado and Wyoming.

The multiple-plot system devised recently by the station was used in inventory work in 1961. Region 1 also used this procedure in its inventory of the northern Idaho national forests. The only variation from the procedure proposed originally was a reduction of the plot grid on each sample acre from 16 to 10.

Overlays showing forest types for seven western states at a scale of 1:5,000,000 were prepared for the Committee on the National Atlas. The project resulted from a committee request that the Forest Service revise the 1949 map, "Areas Characterized by Major Forest Types in the United States."

Wood Density Survey

The Forest Survey organization completed its second field season collecting increment cores and related data from sample western softwood trees. About 4,000 increment cores were collected in Idaho, Montana, Wyoming, and Utah from 638 sample field locations and were sent to the Forest Products Laboratory for processing. Financial assistance to speed up this survey was arranged in a cooperative agreement between the Forest Service and the West Coast Lumbermen's Association, the Douglas-fir Plywood Association, and the Western Pine Association. The station has completed its collection of increment cores from South Dakota, Utah, and Wyoming. Collection in Idaho, Montana, Arizona, New Mexico, and Colorado is scheduled for completion in 1962.

Aerial Photo Interpretation

Emphasis in photogrammetric research is still being placed on photo interpretation techniques and training methods useful to the field technician. Besides aiding Region 4 in its annual photo interpretation school, we participated in the Forest Survey spring training session for student employees and in a special Bureau of Land Management timber estimating school in Colorado. There we demonstrated aerial timber estimating techniques developed from recent photo research at the station.

Demand for the handbooks and training kits on "Basic Techniques in Forest Photogrammetry" remains high. Forest Service requests account for more than half of the 1,700 training kits distributed to date; universities have requested about 25 percent, and foreign distribution has climbed to about 10 percent of the total.

Development of aerial volume tables and aerial estimating techniques has been a major portion of our photo research. We are now compiling a preliminary table for estimation of cubic volume and fence posts in pinyon-juniper stands, and are collecting data for aerial photo volume tables for aspen stands.

We are also investigating use of aerial photo techniques in studies of fish and game habitat. About 1,000 ground cross-sections measured on fishing streams this summer as part of recreation research are being measured on aerial photos; these will be studied to determine the usefulness of photo techniques in recreation research projects. We are studying techniques for photo measurement of lake area and depth. Development of photo techniques useful in fish and game management should be of considerable interest to the wildlife manager.

Products Survey in Utah and Nevada

A census of timber products output was conducted in Utah and Nevada during 1961, covering the year 1960. These surveys are conducted periodically in cooperation with the Bureau of the Census. The items canvassed were lumber, sawlogs, round mine timbers, poles, posts, excelsior bolts, and other wood products. Our compilations showed that Utah produced about 14.8 million cubic feet of timber products in 1960, of which nearly 87 percent was sawlogs for lumber; more than 4 percent went into round mine timbers, and the remainder, about 9 percent, appeared as excelsior, utility poles, posts, converter poles, fuelwood, and miscellaneous farm timbers.

Wood Used by Manufacturing Industries in 1960

This division participated in a nationwide Forest Service-Census Bureau survey of wood used by manufacturing industries. This survey inquired into the use of lumber, bolts, veneer, plywood, hardboard, and particle board for products made (1) for sale, (2) for packaging, handling, and shipping of manufactured products (pallets, skids, containers, dunnage, blocking, etc.), and (3) for jigs, models, patterns etc. used in manufacturing individual firms' products. The last survey of this kind had been in 1948.

ECONOMIC STUDIES

Several years' study of problems of timber growing in the Clark Fork drainage of western Montana was completed this year by preparation of two station research papers "The Opportunity of Thin and Prune in the Northern Rocky Mountain and Intermountain Regions" and "Management for Commercial Timber, Clark Fork Unit, Montana." Both these reports emphasize the need for intensifying forestry efforts, at least on the better sites. They point out:

- That the productivity of a high proportion of the natural stands is low, particularly those established following logging.
- That thinning and pruning will greatly improve yields and values.
- That the only real possibility for profitable timber growing lies in an accelerated program of stand regeneration, thinning, and pruning.

This study strongly emphasizes the need for upgrading the forestry effort, but we need to go further and establish *how much silviculture is justifiable under different circumstances.* That question is being considered in the North Slope study in Utah, now nearing completion. The North Slope area includes much relatively poor site land.

All our deliberations thus far point to the conclusion that *intensive silvicultural practice on part of the forest will in the long run be more economical than low-pressure forestry on all of it.*

Multiple Use

The multiple-use study mentioned earlier is directed toward wild lands of Utah; they typify the problems and opportunities in much of the Intermountain area. This study is concerned with these broad questions:

- What does Utah's wild land contribute to the economy and welfare of the State?
- What sort of economic structure has been built on this dependence?
- What are the limits of the land for producing different values, and what are the nature and extent of the abuses and conflicts resulting from overuse?
- To what extent does land abuse as the conservationist defines it, justify corrective action when costs and values are taken into account?
- What types of development and management of the wild land will best serve the

This gully and much other damage to the land should never have happened. However, the question now is, what part of land deterioration should merely be written off as a bad debt, and how much justifies corrective action. Such multiple-use questions as these require understanding of the costs and values involved.

interests of Utah's citizens and others dependent upon the land in one way or another?

RECREATION

Our first work in the recreation research project was to prepare an overall analysis of recreation opportunities and problems on national forests in the station's territory. Two points stand out in this first glimpse of the situation. First, the national forests have a big recreational opportunity with a flavor all its own that has not yet been exploited. Second, the concentrated wear on focal points of recreation, such as campgrounds, requires strong treatments.

The station this year started a study of the fisheries resource on the North Slope of the Uinta Mountains in Utah. This study is in cooperation with the School of Forestry, Utah State University, and with Region 4 of the Forest Service. One objective is to develop some streamlined techniques for inventorying lakes and streams in a way that will help the land manager know what he has. Our more important objective is to develop a better understandting of what is involved in providing a desirable type of fishing opportunity and also how the lakes and streams as places to fish fit into multiple-use management.

FOREST ENGINEERING RESEARCH

This year Intermountain Station broke new ground in starting a program of forest engineering research. This program was set up in response to demonstrated needs and will materially aid in rounding out and balancing the station's total program. A project leader has been appointed, and additional appointments will be made in 1962.

Predominance of small stems, small volume of production per acre, and low wood value in a country characterized by rough, steep topography make it necessary to find cheaper, more efficient ways to harvest this timber. Land managers are increasingly concerned about damage to land and forest reproduction on steep slopes, especially where such damage has resulted from use of conventional methods of timber harvest and systems of transportation. Forest management in recent years has become increasingly intensive, but the engineering of machines and harvest systems has not kept pace with development of techniques of good forest management. Of similar importance are the development of better mechanical methods of stand improvement and planting in steep, mountainous areas. Also needed are more efficient and economical road design and construction in steep erosive soil. Our projected program embraces research designed to meet these important needs, and fits into already established programs of research in the silviculture of lodgepole pine.

The Forest Service chose the Montana State College campus at Bozeman as the locale of this program in accord with standard criteria for locating projects; namely, nearness to the problems to be studied; nearness to sources of cooperation with industry, land managers, and other professional assistants; and presence of desirable research "climate," including availability of other scientists for consultation, laboratory facilities, library, and special equipment. Bozeman is in the heart of about 10 million acres of small-stemmed lodgepole pine, much of which grows on steep slopes. The Montana State College, with its excellent division of engineering provides ideal atmosphere for our research program.

The kind of forest engineering program we contemplate requires an imaginative approach leading to major innovations and improvements in present concepts and methods rather than minor improvements or gadget development. Its main objective will be to solve engineering problems associated with forest management and utilization peculiar to the small stem and steep-slope forests of this region. Such a program will require specialists in civil, mechanical, electrical, hydraulic, and other branches of engineering. Hence the opportunity for close association of our scientists with personnel of an excellent engineering school is advantageous. The college faculty is available both for consultation and for part-time participation in research problems of mutual interest. Likewise, students may do needed research as part of their graduate requirements.

The decision to establish part of our research program at Bozeman in no way affects station plans to continue major research at Missoula. In fact, several projects there will be expanded. The same criteria that determined location of part of our research program at Bozeman had previously governed establishment of the programs now operating in Missoula.

Montana State College has furnished a site for a Forest Service research unit on the south side of the campus, not far from the present engineering laboratories. The architect's sketch shown on the front cover shows an office-laboratory building (upper left), the first phase of this Forest Service building program, which is scheduled for construction in 1962. At the right is a forest engineering research building; the other two structures are a lathhouse and greenhouse that will be used by the forest management and range management projects also located at Bozeman.

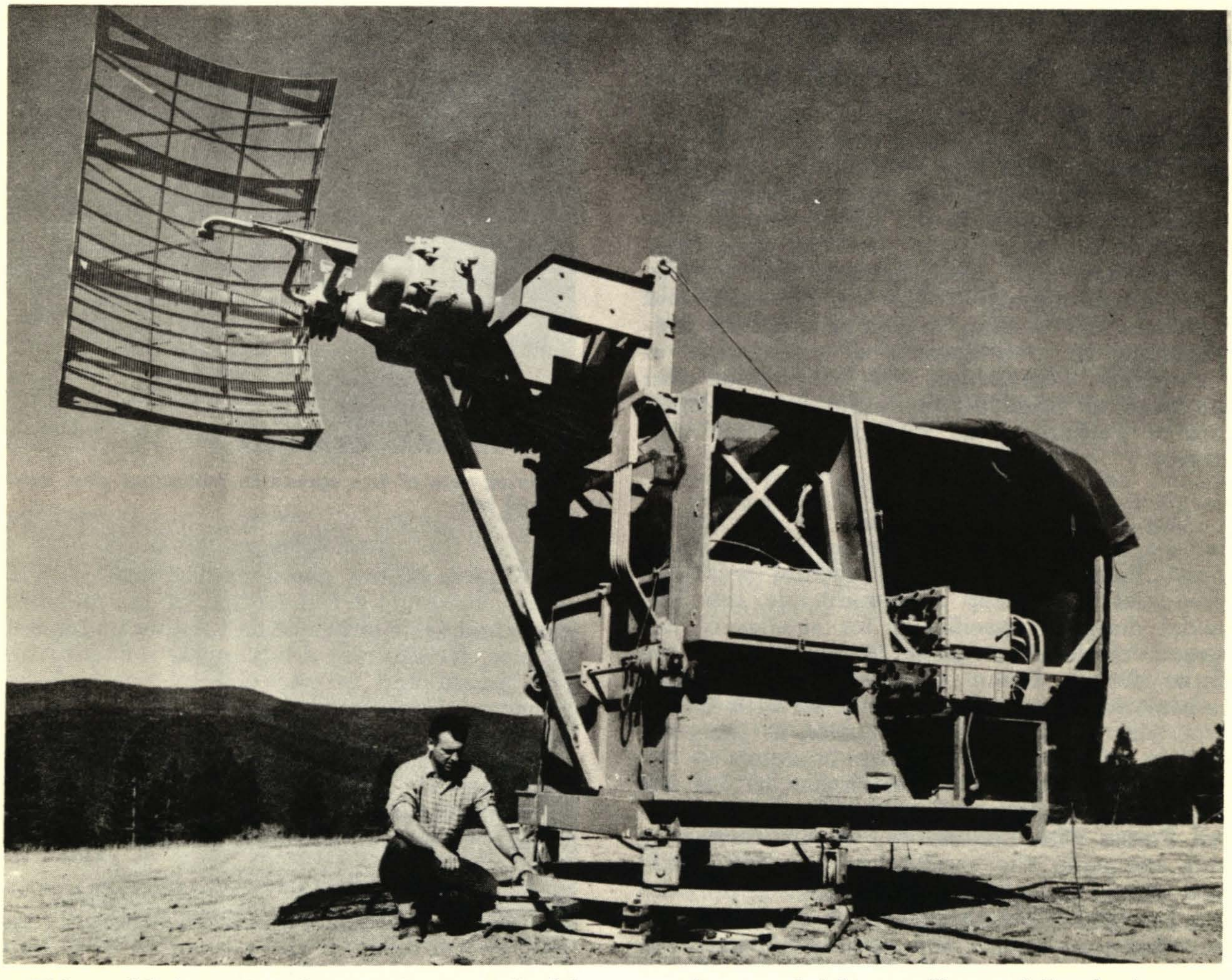
FOREST FIRE RESEARCH

In the 1961 fire season, more than 13,000 fires burned about one-quarter million acres in western national forests. Thousands of additional fires burned on lands protected by other federal, state, and private agencies. Thousands of firefighters waged a summer-long battle against the greatest outbreak of forest fires over the Intermountain West in 20 years. This fire season emphasized fundamental importance of the priority targets in our program of fire research.

Two salient phases of the total program of fire research are: (1) development of certain basic knowledge so that tools for fire control already developed can be used more effectively, and (2) development of new knowledge that may lead to methods of fire control now still in the "dream" stage such as:

- Electronic systems for detection that can "see" fires night or day and that can penetrate haze and smoke.
- Automatic measurement of fire weather and fuel flammability.
- Chemical and mechanical systems that will effectively reduce fuel flammability.
- Knowledge of fire behavior that will promote accurate prediction of fire development and movement.
- Cloud-seeding techniques that may prevent lightning fires.

Fires in the 1961 season demonstrated both the value of recent developments in fire control and the need for continued development of improved capabilities for fire prevention and detction. Events of this season also left little doubt that such things as fire-danger rating, aerial attack, fire retardant chemicals, and campaigns for prevention of man-caused fires really pay dividends. In some of the early historic fire seasons that resembled the 1961 season, the burned area and toll in natural resources was many times greater. But current losses are still too high and must be reduced if the natural resource needs of a growing Nation are to be met.



This modified search radar, rotating on a fixed base, permits range-height surveillance of thunderstorms.

NORTHERN FOREST FIRE LABORATORY

The first full year of operations at the Northern Forest Fire Laboratory practically completed transition to the expanded opportunities for research now possible with the new scientific facilities. This year's major operations included installing and testing of equipment, training operators, and developing research techniques. We started programs for calibrating systems that control the airflow, temperature, and moisture in the combustion laboratory and the wind tunnels; and by the end of the year we were burning experimental fuel beds in both facilities.

In October we received the first signals on the Fire Laboratory radar scope. It is connected by coaxial cable to a master control set at the U. S. Weather Bureau airport station, and from there by microwave relay to the Point 6 radar station atop an 8,000-foot peak near Missoula. Completion of this joint Weather Bureau-Forest Service project provides a unique facility for fire research. This powerful radar will materially aid studies of lightning storms and other atmospheric phenomena over a radius of some 250 miles, an area of more than 60,000 square miles.

FIRE PHYSICS AND ENGINEERING RESEARCH

In the national program of forest fire research, the fire physics and engineering project at Northern Forest Fire Laboratory is designed to study natural laws and basic principles that govern free-burning fires. The complete program will include study of thermophysics, thermochemistry, fire aerodynamics, fire models, and fire measurements. The four physicists and engineers now working in this program are concentrating on investigations of mechanisms of fire spread. This project is in cooperation with the National Science Foundation and the Institute of Technology at Washington State University.

Fire Spread in Natural Fuels

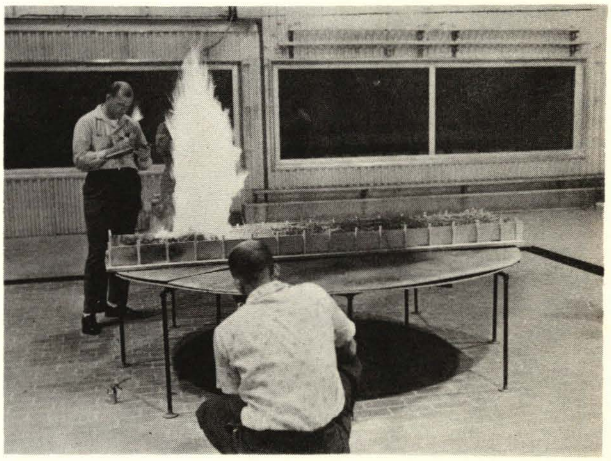
Our first analytical studies of fire spread involve use of a bed of homogeneous natural forest fuels. For this experimental work we have had to develop a reproducible fuel bed model designed specifically for studies of fire spread mechanisms along a segment of the flame front. Using ponderosa pine needles as basic fuel, we have experimented with a mat-type fuel bed that can be burned in the combustion laboratory and the wind tunnels.

On a moving fire table, similar to the one being used on Project Fire Model at the Southern Forest Fire Laboratory, we are measuring and analyzing the mechanisms of fire spread in a steady state fire. Instrumentation provides for 24 channels of thermocouple measurements in various sectors of the fire, directional radiometer measurements, flame photography, and control and measurement of the atmospheric environment in which the fire is burning.

Further studies in the natural fuels now planned are designed to identify, describe, and explain specific mechanisms of fire spread; this in turn will aid studies in fire behavior and control.

Fire Spread in Single and Multiple Fuel Elements

Concurrently with this study in natural forest fuels, we are investigating fire spread in single fuel elements. The Institute of Technology at Washington State University is developing a mathematical and physical model based upon flame spread in a single wood dowel. We shall experiment with this model by burning single fuel elements and studying the loss of weight versus time, thermal radiation at a point near the fire, flame characteristics, and temperature distribution around and above the fuel element. This work will be advanced to multiple fuel elements as correlation between theory and experimenting is developed. In addition, results of these investigations will be analyzed in relation to the findings from experiments in the more complex natural forest fuel beds.



Studying rate of fire spread in ponderosa pine needle fuel bed.

Fire Aerodynamics

Studies of fire aerodynamics deal with the forces exerted by the motion of air and other gases and their influence on the thermodynamics of fire. We are now studying air inflow to fires, fire spread and propagation by wind, the influences of the convective column on fire behavior, aerodynamic properties of firebrands, and relation of wind to fire suppression agents and systems. These studies have required us to develop detailed techniques for use of the combustion laboratory and wind tunnels.

FIRE BEHAVIOR RESEARCH

Research in fire behavior is directed generally toward analysis and evaluation of different combinations of weather, fuels, and topography, and to development of systems for predicting expected fire behavior under these several combinations. Individual studies include physical and chemical properties of fuels, fire environment, fire-danger rating, and evaluation and prediction of fire behavior.

Properties of Forest and Range Fuels

Our studies of physical and chemical properties of fuels include determination of calorific values, chemical composition, physical structure and distribution of fuel particles, description and evaluation of periodic physical and chemical changes, moisture content and distribution, and description and measurement of fuel complexes in various plant associations and forest types.

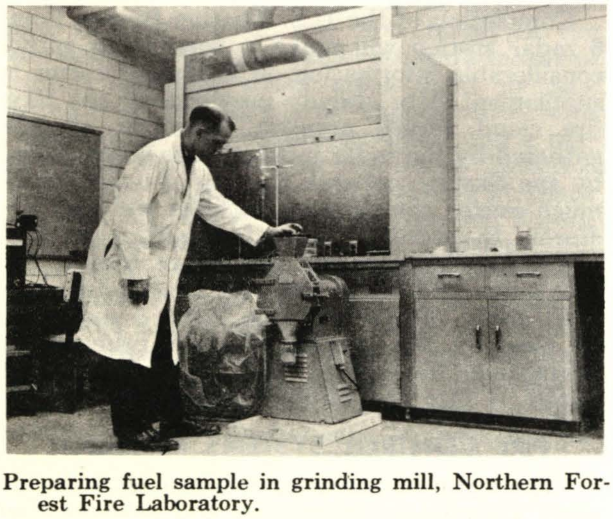
In cooperation with Montana State University, we recently completed a study of ignition delay, which is the duration of temperature influence until ignition occurs at a fixed inlet of oxygen per unit of time. For this study, sphagnum moss, ponderosa pine needles, and cheatgrass were uniformly ground and held at 7 percent moisture content for tests in a Jentzsch ignition tester. At oven temperature of 314° C., ignition delays for these fuels were:

Sphagnum moss	20 seconds
Cheatgrass	28 seconds
Ponderosa pine needles	40 seconds

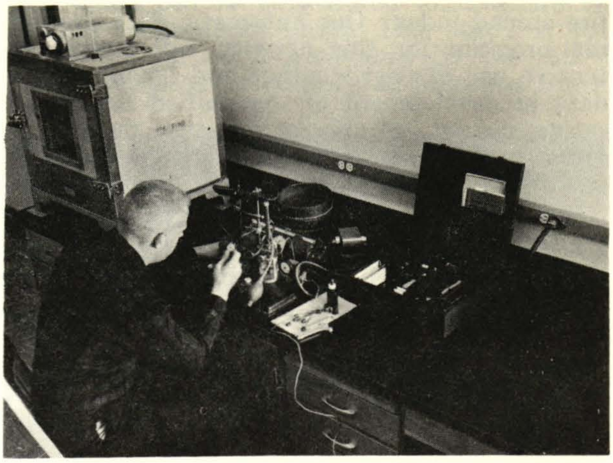
The significantly different flammability characteristics shown by these rates of ignition delay have yet to be studied in terms of physical and chemical properties of the separate fuels.

Fire-danger Rating

Two main projects associated with fire-danger rating are analysis of fire season severity and assistance in developing of a unified fire danger rating system for use throughout the United States, including Alaska.



Preparing fuel sample in grinding mill, Northern Forest Fire Laboratory.



Testing ignition delay with the Jentzsch ignition tester.

Many techniques have been tried in attempts to devise a meaningful system for comparing a given fire season with others. This year we experimented with a system that measured the departure of the current 5-day cumulative severity index from the average 5-day cumulative severity index plotted as a straight line. The severity index, based upon cumulative fuel moisture, evaluates the relative dryness of forest areas.

The new seasonal severity analysis system facilitates comparison of current ratings of dryness with long-term trends, and illustrates clearly the speed of buildup of fire danger as well as speed of seasonal breaks and recovery. The 1961 seasonal severity analysis graphically describes the characteristics of the season in the Intermountain West. In Region 1 the severity index departed furthest above normal on the southern tier of forests; amount of departure decreased in the more northerly forests. Conversely, in Region 4 the northern forests showed greatest increase above the 5-day cumulative severity index curve, and the stations in the southwestern part of the region showed severity index ratings well below average in August. Evaluations corresponded remarkably well with the periods and places of major forest fire troubles in 1961.

Fire-danger rating throughout Intermountain Station's territory is now facilitated by designation of one research fire weather station on each national forest. Any new developments for field use can now be evaluated first at these 34 specially selected and maintained weather stations. Extensive records from these stations will be maintained at the Northern Forest Fire Laboratory.

During 1961 we started analysis on the first index planned for incorporation in the national fire-danger rating system. In cooperation with Regions 1 and 4 we prepared fire data summaries for use in analyzing an experimental fire spread index. Our automatic data processing program for this activity will permit extensive use of past weather and burning index data in development of the unified fire-danger rating system. Studies of moisture recovery of forest fuels will be applicable to the buildup index in the national fire-danger rating system.

Fire Behavior Prediction and Evaluation

In 1961 we again participated in the national fire behavior training program at the Forest Service training school held at Asilomar Beach in California. We also participated in fire behavior training by Forest Service Regions 1 and 4. Future training will be aided by use of the facilities available at the Northern Forest Fire Laboratory. A viewing room permits forest officers to witness fire behavior demonstrations in the combustion laboratory, and provision for closed circuit television will also permit fires in the wind tunnels to be watched in the viewing room.

PROJECT SKYFIRE

Project Skyfire made important progress this year in studies of weather modification and studies of characteristics of lightning strikes and lightning storms.

Weather Modification

The second field season of our lightning modification research program was completed this year. The National Science Foundation and and the U.S. Weather Bureau are assisting in this project. In a specially instrumented area on the Deerlodge National Forest, lightning storms were seeded according to a randomized statistical design. Clouds were seeded by two aircraft equipped with silver iodide generators developed by Project Skyfire and by additional generators strategically located on the ground.

A network of field meters measured lightning discharges, and a group of five spotting stations located lightning strikes. Our experiments in this area enabled us to compare seeded with unseeded storms and gave much new information about lightning storms and strikes.

During the experiments in 1961 we recorded 4,262 lightning discharges, of which 1,686 were cloud-to-ground lightning strikes. Of this total, some 3,339 lightning discharges are suitable for statistical analysis according to the design of the experiment. These data when coupled with similar data recorded in 1960 provide extensive information about modification of lightning storms.

Analysis of records for the past 2 years indicates an apparent reduction of about 38 percent in cloud-to-ground lightning in seeded storms. Frequently however, this preliminary analysis is based on too small a number of storms to be statistically significant. The following table summarizes the record of lightning discharges in 1960 and 1961 on treated and untreated days.

Number of lightning events on treated and untreated days, 1960 and 1961

Year	Untreated		Treated	
	Number of cloud-to-ground events	Number of intercloud events	Number of cloud-to-ground events	Number of intercloud events
1960	236	332	21	163
1961	746	955	590	1,018
Total	982	1,287	611	1,181

Analysis of these data shows no statistically significant difference between treated and untreated experimental units in total number of events, total number of cloud-to-ground events, or total number of intercloud events ($P = 0.25$ in every case). Thus the probability is 0.25 that whatever difference occurred could have occurred by chance. A larger sample will be required in order to reach a statistically significant conclusion. The Project Skyfire cloud-seeding experiments will be continued for gathering additional basic information about lightning and weather modification processes.

Lightning Strike Characteristics

Preliminary studies of intensity of lightning strikes indicate an average electric moment of about 100 coulomb-kilometers. Data on several strikes that have started fires have shown about this same intensity; they also show that strikes that start fires are not more intense than strikes that do not. We are continuing studies to determine whether strikes that start fires differ in any way from those that damage trees without causing ignition.

In June we began a study of tree characteristics in relation to damage by lightning strikes. We classified 54 recently damaged Douglas-fir trees according to seriousness of damage and estimated values for 22 variables for each tree. It is noteworthy that none of these trees showed apparent bole damage near their tops.

Lightning Storm Characteristics

Completion of the U.S. Weather Bureau Point 6 radar station will make it possible to gather considerable information on lightning storms to supplement data already provided by the Skyfire cloud survey network. Analysis of data gathered by the radar in relation to observations by the Skyfire network stations should give us much better comparisons between wet and dry storms, those with many or few lightning strikes, and those forming and moving in frontal disturbances and those growing and existing in local areas. For a time the Point 6 radar will be used by the Weather Bureau primarily in operational forecasting, but we hope to incorporate it into the Skyfire program shortly.

FIRE CONTROL SYSTEMS RESEARCH

The basic objective of this project is to develop knowledge, techniques, and systems that can be applied to planning and managing fire control operations. Separate but related studies include means of preventing man-caused fires, fire detection, fire suppression, hazard reduction, prescribed use of fire, operations analysis, and systems design. We are now concentrating on studies of fire detection, suppression, prescribed use of fire, and special aspects of fire control in Alaska.

Alaska Project

We have completed intensive field investigation of problems of forest fires in Alaska. This has been a cooperative project with the Bureau of Land Management.

During 1961 the Northern Forest Experiment Station, with headquarters at Juneau (formerly the Alaska Forest Research Center), activated a fire research project based on the findings of our preliminary work. The project leader of the new Alaska fire research activity will give on-the-ground leadership to research on critical problems in Alaska. We shall continue to aid this program by furnishing technical assistance and by performing laboratory experiments that cannot be done in the field or at the limited laboratory facilities in Alaska.

Fire Detection

Prompt, accurate location of fires is basic to effective control. Recent analyses emphasize the importance of improving the capabilities of fire detection systems and possibly lowering their cost. The Alaska fire analysis demonstrates urgent need for earlier detection in vast wilderness forests. Other western states also need better fire detection, especially at night and during periods when smoke and haze restrict visibility. Several new scientific developments, particularly in electronics, point to opportunities for solving some of these problems in detection. Accordingly we have activated a research program that will attempt to develop more efficient fire detection methods.

Since lightning is the number one fire starter in western forests and causes the most damaging fires in Alaska, our first target in fire detection is to develop quick, accurate means of locating lightning strike areas night or day. During the 1961 season we experimented with a combination of 3-centimeter radar and a narrow band sferics receiver to detect lightning strike areas. Equipment was installed at Black Pine Lookout on the Deerlodge National Forest, where supporting facilities of Project Skyfire could aid the work. Radar storm tracking was verified by data from the Skyfire lookouts.

Results of this season's work show the need for a better system of identifying lightning strike areas. Radar can effectively track storm cells but cannot identify which ones are producing lightning. Preliminary analysis is now under way to determine whether a pair of special sferics receiver stations located 300 or more miles apart can be substituted for a group of separate radar-sferics units. This study is being carried out with assistance by the Electronics Research Laboratory at Montana State College.

Radar installation at Black Pine Lookout for research in fire detection.

Our second target is to develop better systems for detecting going fires regardless of their cause. Recent advances in research point to the possibility of using the principles of infrared for this purpose. New information on the attenuation characteristics of moisture, tree crowns, and some types of smoke indicate possibilities of employing airborne infrared scanning devices for fire detection. With cooperation from the U. S. Army Signal Corps we are planning a definite program of research in use of infrared systems for (a) detecting fires through smoke and forest canopies, (b) locating the perimeter of going fires and finding hot spots and spot fires when the area is obscured by smoke, and (c) determining rate of fire spread from successive scanning flights.

Suppression

Last year more than a million gallons of fire-fighting chemicals were dropped from aircraft operated by a single Forest Service unit. Yet despite this great use of chemicals we have only imperfect knowledge of the chemistry of forest fire extinguishment and so far have developed no precise means for properly evaluating the effect of chemicals or for rating their essential characteristics as fire retardants or suppressants. Until now we have not had facilities for making needed analytical studies. Late in 1961, in cooperation with the Pacific Southwest Forest and Range Experiment Station, we made plans to study such chemicals in the combustion laboratory and wind tunnels at Missoula. In this cooperative program we hope to learn the effect of various chemicals on forest fuels. Wind speed, fuel moisture, air temperature, and relative humidity will be varied and controlled in these experiments. We hope that results of this study will help develop urgently needed guides for proper selection and application of fire-fighting chemicals.

FOREST INSECT RESEARCH

INSECT STUDIES

Douglas-fir Beetle

The long-term study of the epidemiology of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., continued this year as planned. Three phases of this study reported here are: (1) relation of oleoresin pressure to age of tree, (2) chemical treatment of standing trees to attract adult beetles, and (3) presence of parasites of Douglas-fir beetle adults.

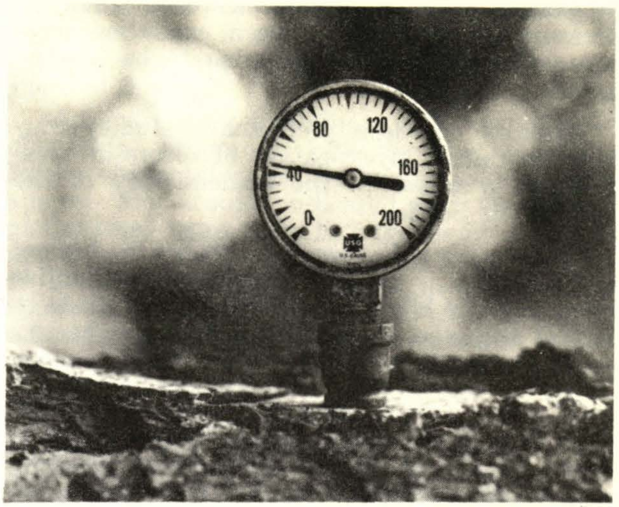
Relation of oleoresin pressure and age of trees.—Workers in California studying bark beetles on ponderosa pine have reported a correlation between beetle attack and low pressure of oleoresin exudation. Observations in Douglas-fir stands indicate that the Douglas-fir beetle prefers overmature trees. To determine whether exudation pressures differ markedly between young- and old-growth fir, we installed gauges (see figure) on eight pairs of young and old trees. Descriptions of these trees and their average maximum pressure readings as pounds per square inch are shown in the following tabulation.

Age (Yrs., av.)	Diameter breast height	Radial growth Last 5 yrs.	Radial growth Last 10 yrs.	Resin pressure
	In., av.	*mm., av.*	*mm., av.*	*psi., av. max.*
82 (young)	13.6	25	50	46
203 (old)	21.5	16	30	19

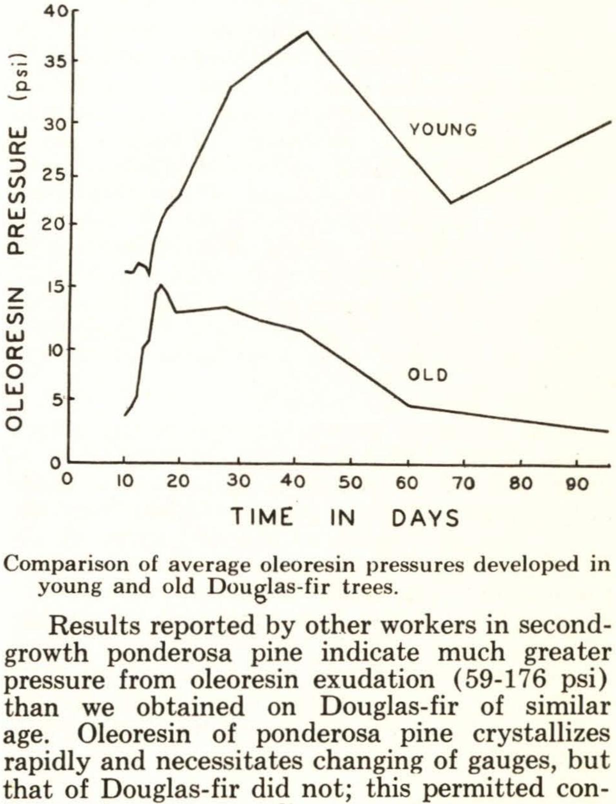
Considerable variation in pressure was recorded even within each age group. Some gauges indicated practically no pressure, whereas one tree attained a maximum pressure of 80 psi. Speed of attaining maximum pressures also varied. Performance of individual trees in this study is shown below.

Young trees: Tree No.	Resin pressure	Days since start	Old trees: Tree No.	Resin pressure	Days since start
	psi, max.			*psi, max.*	
1a	46	10	1b	14	10
2a	32	60	2b	9	10
3a	71	12	3b	24	28
4a	10	8	4b	40	7
5a	12	51	5b	2	7
6a	46	32	6b	0	....
7a	80	32	7b	61	19
8a	66	85	8b	0	....

Average oleoresin pressures within groups of young and old trees (see graph) over a 3-month period are expressed as follows:



Pressure gauge used to compare oleoresin exudation pressure of young and old Douglas-fir in study of susceptibility to bark beetles.



Comparison of average oleoresin pressures developed in young and old Douglas-fir trees.

Results reported by other workers in second-growth ponderosa pine indicate much greater pressure from oleoresin exudation (59-176 psi) than we obtained on Douglas-fir of similar age. Oleoresin of ponderosa pine crystallizes rapidly and necessitates changing of gauges, but that of Douglas-fir did not; this permitted continuous long-term readings.

Tendency toward higher exudation pressure in young Douglas-fir than in mature trees seems to be only one factor accounting for the preference of the beetle for older trees. However, if old-growth trees for some reason generally attract the beetle, the fact that some old-growth trees resist attack might be explained by individual differences in exudation pressure, as observed in this study. Likewise, if young Douglas-fir are not generally attractive to the beetle or even repel it, some of them may escape infestation in spite of low oleoresin exudation pressure. Correlation between exudation pressure and beetle attack remains to be investigated.

Results of these preliminary studies warrant continued investigation of oleoresin pressures as a factor in the epidemiology of the Douglas-fir beetle.

Treatment of standing trees to attract adult beetles. — In 1960 we determined that live trees could be killed with herbicide and made to attract and trap adult beetles. If enough beetles could be trapped in this manner, an infestation might be controlled (less expensively) by logging than by other available means. The problem of using trap trees to control this beetle is that no presently known methods of preparing such trees trap enough beetles to be economically efficient. Consequently we are continuing to study methods of treating trees to make them more effective as traps.

This year we investigated the effects of low dosages of ammate (ammonium sulfamate) crystals introduced into the base of live standing trees. Dosages of less than ¼ cup per tree caused some fading of foliage on mature trees; this indicated extreme sensitivity of Douglas-fir to small amounts of ammate. Only trees given 1 full cup of ammate died. Death of the tree, followed by beetle attack, was more certain when 1 cup of ammate was divided and introduced at four locations around the circumference of the stem rather than two. Of nine trees killed by ammate, five were subsequently infested by the beetle.

The following tabulation records the attack density and brood density of infestation of these five trees. Counts of attacks were made in ½-square-foot bark samples taken from the north and south sides of infested stems at 10-foot intervals. Eighty samples (4.17 percent of the infested bark) were examined. Calculations indicated that each tree contained an average of 4,460 attacks and 24,660 live progeny. About 30 percent more attacks and 12.5 percent more progeny occurred on the north than on the south sides, but this difference was not entirely consistent.

Tree	Age	Diameter, breast height	Tree height	Infested length	Douglas-fir beetle	
					Attacks	Progeny
	Years	*Inches*	*Feet*	*Feet*	*Number per tree*	
1	180	19.1	97	54	2,200	7,700
2	Not determined	18.7	111	55	2,100	3,100
3	276	30.4	135	107	8,600	36,700
4	259	32.9	128	90	4,300	37,100
5	274	25.4	101	76	5,000	38,600
Av.	247	25.3	114	76	4,460	24,660

Densities of attack shown in the tabulation above compare well with those observed occurring naturally in standing trees. These were probably the most efficient traps we have created. Further increase in density of attack may possibly result from development of more effective attractants through research. Trap trees still lack efficiency needed for large-scale control. Meanwhile, the ammate treatment enables us to select locations for and create adequate numbers of infested trees for study. This saves valuable time normally consumed in searching for infested trees and helps us obtain more data by concentrating study trees within problem areas.

Parasites of adult Douglas-fir beetles.—We are studying biological agents acting to regulate populations of Douglas-fir beetle. A parasitic wasp, *Tomicobia tibialis* Ashm., appeared in southern Utah in 1959 in parent Douglas-fir beetles. This was the first record of such parasitism among adult *Dendroctonus* beetles, which include 24 species. We have searched for this parasite in other areas, but so far have found it only in Garfield County, Utah. This parasite develops in the abdomen of its host and eventually kills it. Bark samples from 40 infested trees examined late in the summers of 1960 and 1961 contained 210 parent beetles, most of which were dead. Of these 122 or 58 percent were parasitized. While examining these parasitized beetles we found several instances of hyperparatitism of *Tomicobia* by another wasp, *Amblymerus confusus* (Ashm.), formerly considered to be a primary parasite of the Oregon pine engraver beetle, *Ips oregonis* (Eich.).

Larch Casebearer

The larch casebearer, *Coleophora laricella*, has rapidly become established since its discovery in Idaho in 1957 and is spreading throughout the Inland Empire. Two phases of continuing studies received attention this year: checking on releases of parasites, and sampling procedures.

Checking parasite releases. — The first of several planned releases of parasites was made in 1960. Approximately 2,400 braconid parasites, *Agathis pumilus*, were released in five colonies around St. Maries, Idaho. Collections of casebearer early in 1961 contained no adults of the parasite. This failure does not indicate that the species has not been established in the area. Populations of casebearer were very heavy and parasite releases relatively small; this considerably decreased chances of recovery of parasites the first year after liberation. Colonization will continue in 1962 with additional releases of adult parasites from infested areas in the East.

Sampling procedures.—Success of biological studies, including measuring effectiveness of biological control factors, depends upon statistically sound methods of measuring populations.

In 1961 we sampled egg populations as the first step in developing sampling procedures. The casebearer lays eggs on individual needles of fascicles. A count showed an average of 38 needles per fascicle for the first crop. The young larvae feed as miners, and if they destroy tissue for more than half of the needle length a second crop of needles is produced. This second crop averages fewer than half as many needles per fascicle as the first.

In the heavy population of casebearers examined, 11 percent of the total number of needles examined had one or more eggs attached. Some needles had as many as four eggs, but it appears that only one larva per needle can survive. Only 53 percent of more than 1,000 eggs examined hatched. Predations is suspected to be a major cause of failure to hatch.

A needle fascicle appears to be satisfactory as a unit of foliage for sampling egg populations of casebearers. Twenty fascicles from four 12-inch twigs from the midcrown of a tree appears to be an adequate sample for an individual tree, but intensity of sampling on an area basis remains to be determined. The casebearer hibernates as an immature larva in its case attached to a twig. Samples have been taken to measure populations entering hibernation.

Western Pine Beetle

Ponderosa pine risk rating. — Long-term studies were started in 1948 in old-growth stands of ponderosa pine in western Montana. Our two main objectives were to determine (1) whether risk rating of ponderosa according to susceptibility to attack by western pine beetle would apply to stand conditions in Montana, and (2) whether selective logging of high risk trees would be an adequate method of control. Data obtained to date were summarized this year.

Approximately 40 billion board feet of merchantable ponderosa pine in the northern Rocky Mountains is in virgin old-growth stands. Plot studies indicated that 96 percent of the trees more than 11.1 inches in diameter are either mature or overmature. An average of 20 percent of the volume in these same stands is in risk classes 3 and 4, which are considered most susceptible to beetle attack.

Mortality from bark beetle attack in test plots to date has been low—only 64 trees. The bark beetle population has been at low level throughout the study. Fifty of the 64 trees that died were within the combined risk classes 3 and 4. These limited data support the premise that high risk trees can be identified prior to attack, but studies should be continued through periods of high population pressures before sound appraisal can be made of the value of the risk rating system in the northern Rockies.

Mountain Pine Beetle

The mountain pine beetle, *Dendroctonus monticolae* Hopk., is a serious pest in lodgepole, western white, and ponderosa pine stands in the Intermountain West. Long-term studies started his year are designed to determine causal factors in population changes. We plan detailed studies of populations and infestations, under varied environmental conditions, in lodgepole stands in Utah and southern Idaho and western white pine stands in northern Idaho.

FOREST UTILIZATION RESEARCH

Analysis of problems of forest utilization in the Intermountain area indicates three broad fields of study that require investigation:

- Wood properties that affect quality and utilization of timber.
- Technology needed for improving utilization of timber.
- Impact of utilization changes on marketing of forest products.

Our major emphasis during 1961 was on study of wood properties.

Studies of Wood Properties

One year ago we reported that field work was nearly completed for a survey of properties of western larch wood. To the 366 plots in Montana, Idaho, and Washington previously sampled, we added 100 this year. These additional plots have provided improved data, but the addition has delayed analysis of the information collected earlier. We are hoping that analysis of the whole mass of data will enable us to describe precisely what effect site and stand conditions have on such properties of western larch wood as specific gravity, spiral grain, sapwood thickness, and tree form.

We took advantage of an unusual opportunity this year to collect data on spiral grain in Douglas-fir. A working group on the National Log Grade project in Montana and eastern Oregon made available materials from about 500 fir trees. Disks were taken from the top end of each 16-foot butt log; after each disk was split, spiral grain measurements were made on the radial edge. These measurements showed that all the trees had some spiral grain. Young, vigorous growth produces left-hand spiral; middle age or "normal" growth shows little or no spiral; but retarded or older growth produces right-hand spiral. Maximum spiral grain measured in the 500 Douglas-fir sampling was 17 degrees, or 1 inch for every 3.24 inches' length. Data from this study will be compared with information gathered from lumber grade recoveries.

Field work for our study of performance of spiral grain in poles has been completed, and the last "pole farm" at Libby, Montana, has been dismantled. We have shipped 10 sample poles to the Forest Products Laboratory for strength tests and certain internal examinations. Preliminary results of the pole study indicate that mere visual examination of the pole surface does not give enough evidence for prediction of a spiral grained pole's service. Analysis of internal spiral grain should give more specific and useful criteria on which to base prediction of performance.

We have completed arrangement with the University of Idaho to undertake a cooperative study of the properties of western redcedar. This species is valued highly for production of poles, lumber, and veneer; but we need much more information about its several physical, chemical, and mechanical properties and about how growth conditions influence these specific properties.

Studies of Improved Technology

Part of this division's work in 1961 was devoted to improving the utilization of Intermountain timber species through encouraging use of better technology. We have continued to consult with industry on the possibilities for drying poles and lumber in high temperature kilns; we have consulted on the veneer and plywood potentials of various species; have participated in developing two charcoal operations; have consulted on establishing new wood processing industries where none now exist; and have been active in numerous local and regional professional and industrial associations. These consultation and liaison functions remain a productive and important part of our total program effort.

Removing spiral-grained poles from experimental site at Libby, Montana. After 4 years of simulated service conditions, they will be tested for strength and related qualities.

Influence of Utilization Changes

The third major phase of our research program has been measuring the impact of various utilization changes on use of wood products. Costs of production cannot be separated from utilization; and the steadily narrowing margin between rising costs of production and relatively fixed selling values has been a major factor limiting the broader use of Intermountain woods.

To better understand these relations and cope with them, we have begun to measure and evaluate the effects of differences in slope, stand density, timber size, and other factors on costs of logging by various cable systems. National Forest Administration and the timber industry are collaborating with us in this study. Some limiting factors are already evident, but a full season's log production cost data will indicate these relations more precisely. This study will eventually lead to recommendations for improved equipment design and operation.

Time data were collected continuously from June 19 through September 11 on more than 800 turns of logs. More such data are needed for critical analysis, but even preliminary analysis has shown that delay time (time when yarding equipment could have been operating but did not) ranged from as little as 8 percent of total elapsed time to as much as 46 percent on some settings. Consequently, average daily production was considerably below what had been expected.

We are preparing plans for comprehensive analysis of how changing utilization technology is affecting marketing economics, and, conversely, how consumer preferences are influencing technology. We recognize, as do most other observers of the wood-using industries, that strong forces are in play, and major patterns of wood consumption may be undergoing change. Part of our work in forest utilization is to identify these changes.

RANGE MANAGEMENT AND WILDLIFE HABITAT RESEARCH

Programs of research in range management and wildlife habitat, like those of some other divisions, were somewhat reorganized in 1961. We believe that the revised programs provide better research and academic facilities than had been available previously and that they add depth to individual projects by bringing together at a single location men who are working on interrelated phases of a given project.

Range management research formerly centered at Spokane and Missoula has been shifted to a single project at Bozeman. This work will be directed toward problems of managing livestock and elk ranges of northern Rocky Mountain grasslands. Planned laboratory facilities provide for increased emphasis on studies of physiological and ecological aspects of range problems.

Research on wildlife habitat management in northern Rocky Mountain forests is now centered at Missoula; this work includes studies previously located at Spokane. Management of understory vegetation important for wildlife, and integration of deer and elk use with timber production in commercial forest types will be emphasized.

Boise continues to be headquarters for two research projects in southern Idaho on (1) cheatgrass and sagebrush-grass range (including Saylor Creek Experimental Range and the U. S. Sheep Station Experimental Range) and (2) on rehabilitation and management of critical deer range. The future program here will also include management of steep rangelands having loose granitic soils. Modest laboratory facilities built this year will facilitate work on soil and ecological aspects of these problems.

Range and wildlife habitat research for the southern end of station territory eventually will be headquartered at Provo and Logan. Work on summer-grazed types – mountain herblands, brushland, and aspen ranges—is now located at Provo, and in the past 2 years grazing studies have been started in cooperation with the Ashley and Uinta National Forests. Range Management research involving desert shrub, sagebrush-grass, and seeded spring-fall range will be combined at Provo into a single project that will include similar research on pinyon-juniper ranges. Game habitat research involving restoration and management of critical deer range is being conducted from Ephraim in cooperation with the Utah Fish and Game Department; the phases involving relations between wildlife and livestock, now supervised from Ogden, will be moved to Provo.

Following are selected examples of current findings.

STUDIES OF LIVESTOCK RANGE

Effect of Slope Steepness on Cattle Grazing

Steepness of slope has long been recognized as a strong influence on utilization of mountain rangelands, but quantitative information about it has been lacking. Our study of the influence of topography and other factors on distribution of grazing by cattle on northern Rocky Mountain grassland ranges is providing useful guides for determining usability of such range.

The proportion of grazing below a specified point (the dependent variable) was highly correlated (0.901) with slope steepness and distance up slope. This relationship accounts for 82 percent of the variation in grazing distribution on the mountainous rangelands studied.

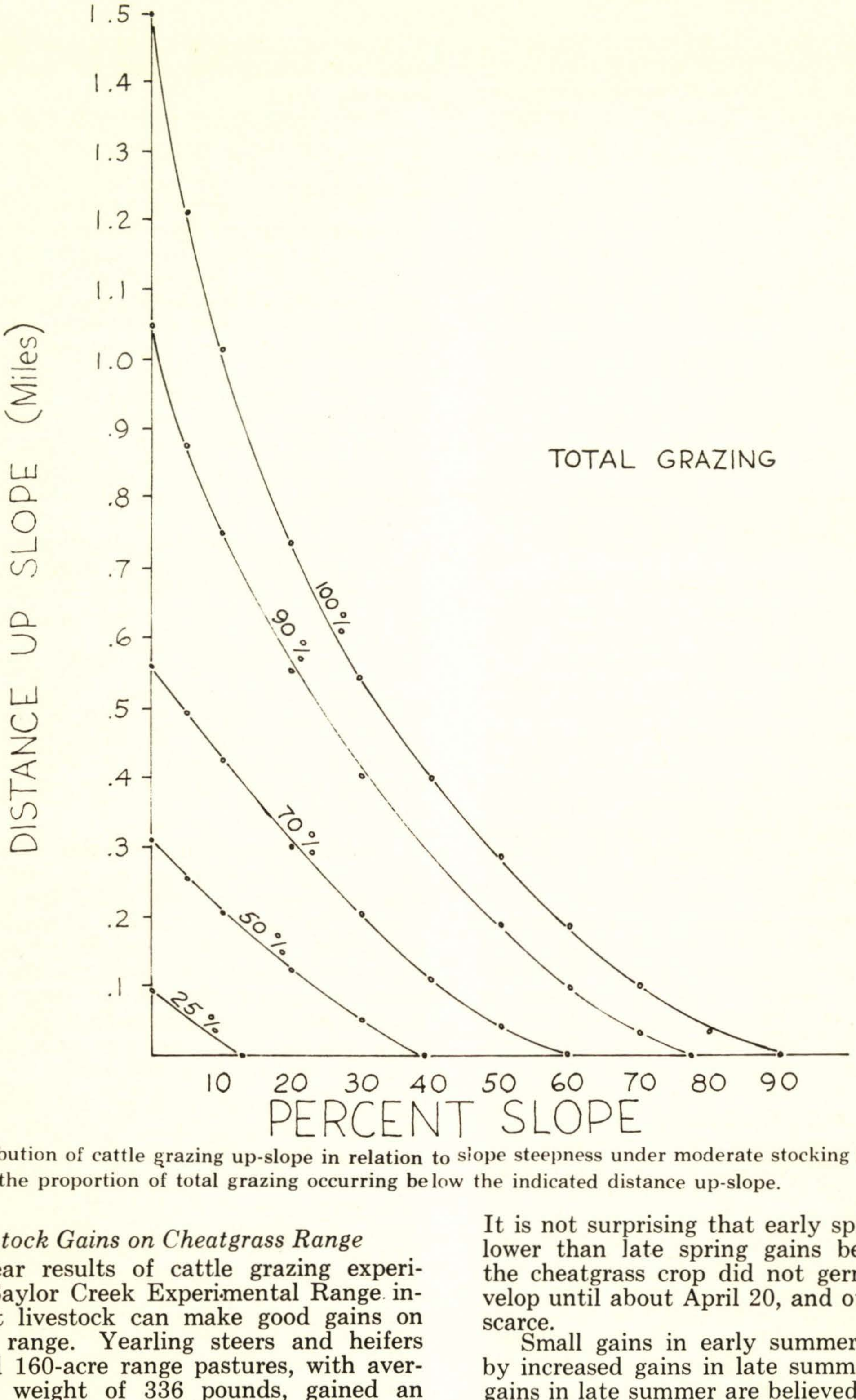
We believe results of our studies are applicable to northern mountain grasslands under the moderate stocking rate of about 2 to 4 acres per cow month seasonlong. Summer grazing under this rate of stocking is likely to show about 90 percent of total cow use within three quarters of a mile of the bottom on a 10-percent slope; within 0.4 mile on a 30-percent slope; and within 0.1 mile on a 60-percent slope.

Cattle Gains on Lower Aspen Zone Range in Utah

Weight gains of mature cattle commonly decline late in the summer. In 1960, this decline was evident for all classes of cattle on the Diamond Mountain grazing study; but in 1961 only the cows (with calves) showed this late summer slump in gains. Variation in gains of the cows differed according to grazing treatment. Pounds gained per head per day are shown in the following tabulation:

	July 15 to Aug. 15		Aug. 16 to Sept. 30	
	1960	1961	1960	1961
Cows	0.73	1.20	−0.71	−0.07
Yearlings	2.03	1.87	.36	1.73
Calves	2.90	2.23	1.58	2.18

These relatively good summer gains, particularly for the calves and yearlings, indicate the value of our high-elevation native rangelands for livestock production. As a means of increasing production and efficient utilization of these mountainous grazing lands, several systems of grazing management are being studied in cooperation with the Diamond Mountain Cattle Users' Association and the Ashley National Forest. This year, mature cows that were moved from one unit to another at midsummer in rotational grazing tended to gain less than those that grazed a single unit seasonlong at a lighter stocking rate. However, gains of yearlings and calves were similar under all grazing systems.



Distribution of cattle grazing up-slope in relation to slope steepness under moderate stocking rate. Curves show the proportion of total grazing occurring below the indicated distance up-slope.

Livestock Gains on Cheatgrass Range

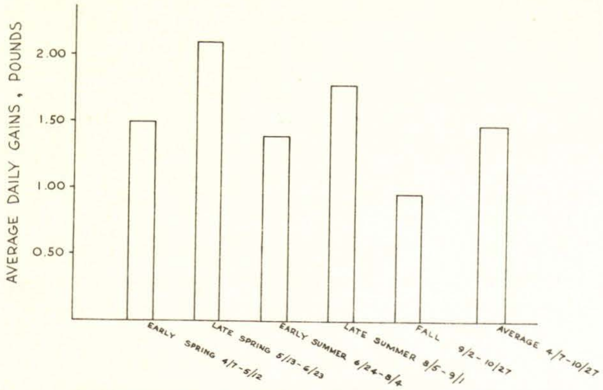
First-year results of cattle grazing experiments at Saylor Creek Experimental Range indicate that livestock can make good gains on cheatgrass range. Yearling steers and heifers on 80- and 160-acre range pastures, with average initial weight of 336 pounds, gained an average of 1.47 pounds per head per day for the period of April 7 to October 27. Total gain for individual animals over the 200-day grazing season varied from 136 to 395 pounds.

Highest daily gains (2.09 pounds per day) were obtained during the late spring period, despite the fact that cheatgrass matured during this 6-week grazing period (see figure, p. 30). It is not surprising that early spring gains were lower than late spring gains because most of the cheatgrass crop did not germinate and develop until about April 20, and other forage was scarce.

Small gains in early summer were followed by increased gains in late summer. These high gains in late summer are believed to be attributable to heavy utilization of Russian-thistle (*Salsola kali*). The thistle, which was immature and quite high in protein during the late summer, made up about 50 percent of the available forage at this season.

Sheep were grazed only for the 35-day early spring period. Yearling sheep, averaging 100 pounds in weight, gained at the rate of 0.34

pound per head per day. This figure is the average for 26 sheep that were rotation-grazed in 5-acre pastures, and 13 others in an 80-acre range pasture.



AVERAGE DAILY GAIN OF YEARLING CATTLE BY SEASONS ON CHEATGRASS RANGE

RANGE TREATMENTS AND STUDIES

Evaluation of Pocket Gopher Control

We are evaluating pocket gopher control on the Cache National Forest in cooperation with the U. S. Fish and Wildlife Service and the Utah State University. One phase of this study involves the degree of control obtained by applying 1080-poisoned grain in the spring for the effects of 1, 2, 3, and 4 consecutive years. Mound numbers were counted as a measure of relative gopher populations. The following tabulation of counts of mounds indicates a large decrease (nearly 50 percent) in gophers the summer following the first poisoning.

Years treated	Mounds per acre (Sept. 4, 1961)	Cumulated cost per acre *(Dollars)*
0	2,649	none
1	1,380	1.08
2	1,093	1.56
3	801	2.04
4	978	2.52

Subsequent annual poisonings were less effective in further reducing gopher numbers, but they were less expensive and apparently kept populations down. Cost figures supplied by the Division of Predator and Rodent Control, U. S. Fish and Wildlife Service, averaged $1.08 per acre for first treatment and 48 cents per acre for retreatment in each subsequent year.

Mound counts on permanently marked plots on the Cache National Forest reveal a sharp die-off in pocket gophers in 1960; but they indicate that 1 year later gopher numbers had partially recovered on open herblands and had reached a new high on the aspen-covered areas:

	Average mounds per acre				
	1957	1958	1959	1960	1961
Open herbland	1,693	1,730	1,503	410	1,113
Aspen-covered area	1,333	1,593	1,127	613	1,827

The die-off in 1960 was less severe on the aspen area, which might account for the more rapid recovery there.

Since this die-off may have influenced the data of gopher-control study, we shall continue the mound counts and gopher trapping in 1962 on this study.

Susceptibility of Four Bunchgrasses to Fire

Needle-and-thread grass (*Stipa comata*) and Thurber needlegrass *(Stipa thurberiana)* are relatively more susceptible to fire than Sandberg bluegrass *(Poa secunda)* and bottlebrush *(Sitanion hystrix)*, according to results from our burning treatments. Plants of each species were divided into small and large size classes and treated with no burn, light burn (approximately 200° F.), and heavy burn (approximately 400° F.) on June 9, July 8, and August 18.

Light and heavy burn treatments produced the same plant response in most species. However, small plants of Thurber needlegrass burned in June and large bottlebrush plants burned in August lost significantly more basal area under heavy burning than under light burning.

Basal area of Sandberg bluegrass, a highly fire-resistant species, was not affected by the burning treatments. Bottlebrush was slightly susceptible to fire during July and August, when burning reduced the basal area of these plants about one-sixth.

Needle-and-thread grass was damaged most by fire. All the small plants and 90 percent of the large ones were killed by the June treatments. In July, basal areas of small and large plants were reduced 82 and 96 percent, respectively. In August, the small needle-and-thread plants were not affected but large plants suffered a 68-percent reduction. The damage to large plants during August was significantly less than that for June and July.

Thurber needlegrass was less susceptible to fire than needle-and-thread. Small plants showed a significant reduction (40 percent) in basal area only for the month of June, but large plants lost basal area in all periods — 92 percent in June, 77 percent in July, and 50 percent in August. Heavy burn treatments in June and July caused the most damage.

On July 13, 1960, a wildfire burned through some of the experimental plots and provided an additional burning treatment. This wildfire reduced the basal area of small plants of needle-and-thread and Thurber needlegrass 59 and 10 percent, respectively, and that of large plants 94 and 89 percent, respectively.

These studies suggest that volume and distribution of fuel within the plant crowns is an important factor in plant survival. The low resistance to fire of large plants of the two needlegrass species may be attributed to increased amounts of fuel in the plant; this apparently produces higher burning temperatures of longer duration in the crown of the plant.

Effects of Grazing and Herbage Removal on Wheatgrass

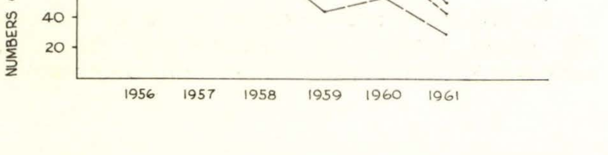
On the Benmore Experimental Range, we observed that grazing and the removal of old herbage by hand following maturity of crested wheatgrass plants stimulates production of seed heads on old stands but does not affect total herbage yields materially except during drought years.

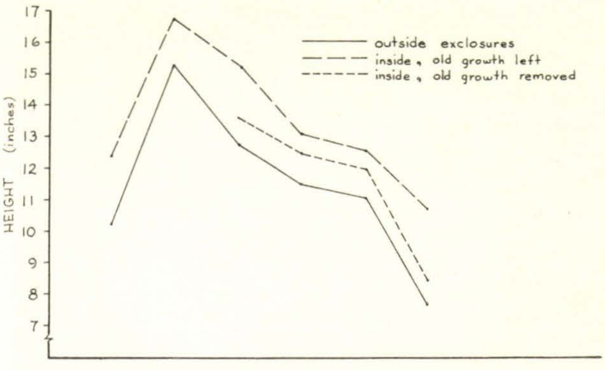
In 1956 we began collecting data on production of seed heads, height growth of seedstocks, and herbage yields for crested wheatgrass growing in exclosures built in 1948 on 10-year-old stands. We applied two treatments to these exclosures: (1) allowed old growth herbage to accumulate from year to year, and (2) removed old growth by hand late in April annually after 1956. We compared data from these plots with records from caged plots established each year on grazed range.

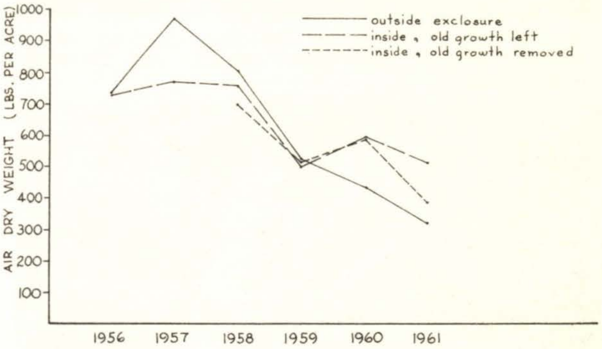
Seed head production was much greater on the grazed range than on the ungrazed (see figure below). Removal of old growth by hand stimulated seed head production, but the number of heads produced was never as great as that on the grazed range. The general decline in production of seed heads from 1956 through 1961, which was most pronounced on the grazed range, was due primarily to low annual and seasonal precipitation.

Height growth of seedstalks was greatest on the ungrazed areas, intermediate where old growth was removed by hand, and least on the grazed ranges (see upper graph col. 2). This is the converse of the results for seed head production. Height growth, like seed head production, fluctuated with precipitation and declined generally during the treatment period.

Differences in herbage yield between ungrazed and grazed range were not consistent (see second graph, col. 2). Yields fluctuated with precipitation and declined markedly in the years 1959, 1960, and 1961, when precipitation was low. Yields on the grazed areas were lower than on the ungrazed area in 1960 and 1961 when drought was severe.







Effect of Early Deer Grazing on Bluegrass

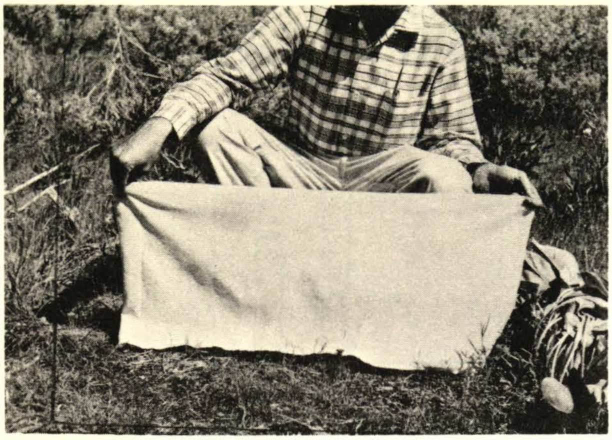
Bluegrasses furnish choice early spring forage for deer and also for livestock later in the spring. Early spring grazing by deer reduces the forage available for livestock.

In studies of Sandberg bluegrass on the Cache National Forest, herbage yields were measured on the following kinds of areas: (a) protected from grazing, (b) grazed by deer at the rate of about 38 deer days per acre, and (c) clipped closely (twice during the early spring season when deer normally grazed the area) to simulate very heavy deer use.

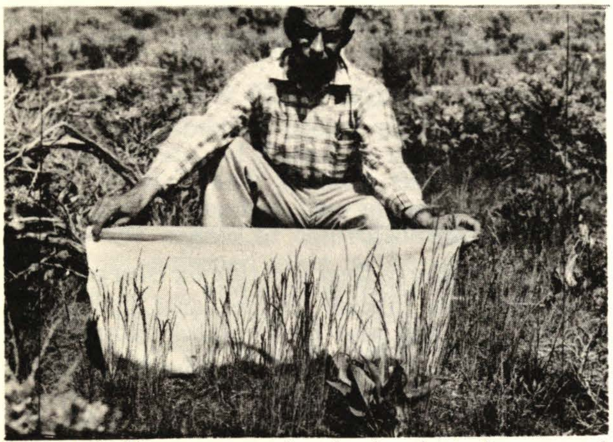
Close clipping in early spring apparently did not reduce total production the first year, but 2 years of close clipping reduced production approximately 58 percent, as shown in the tabulation below. Residual production, that available for livestock, was only 40 percent of the total production the first year of treatment and 15 percent the second year.

	Clipped	Grazed by deer	Protected
1957			
Herbage clipped early	171	(1)	....
Residual (end of season)	120	177	241
Total	291	(1)	241
1958			
Herbage clipped early	148	(1)	....
Residual (end of season)	26	167	416
Total	174	(1)	416

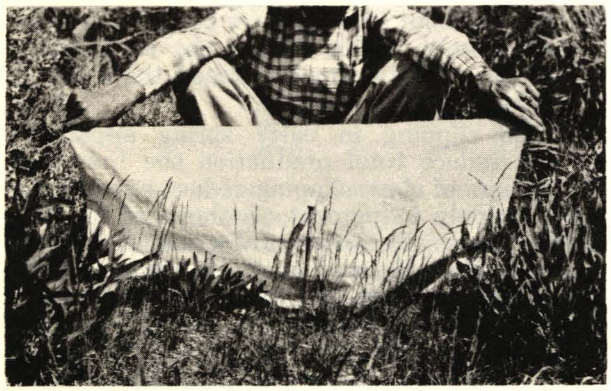
[1] Herbage removal by deer and total yields could not be determined because areas were grazed by deer during the early spring growing season.



Close clipping twice during the deer grazing season greatly reduced subsequent growth and seedstalk production.



Protected bluegrass produced abundant forage and many seedstalks.



Early spring grazing by deer reduced number of seedstalks and volume of forage available for livestock.

These data, from treatments assigned at random and replicated 14 times, were not significantly different from those on the protected plots at the beginning of the study; therefore, they indicate diminishing yields of total bluegrass herbage and also of the residual available for livestock.

Seedstalk numbers and size, which are indicative of vigor, were drastically reduced both by clipping and by deer grazing, as shown in the following tabulation:

	Protected	Grazed by deer	Clipped closely
Seedstalks per 9.6 sq. ft. (1957)	44	17	10
Seedstalks per 9.6 sq. ft. (1958)	370	226	10
Weight (grams) per stalk (1958)	.032	.021	.011

Effects of early deer use on bluegrass and the subsequent reduction in forage available for livestock must be considered for integrated management of deer-livestock range.

WILDLIFE HABITAT STUDIES

Deer-Elk-Cattle Range Relations

In spring and fall, deer and elk prefer native browse and aspen range to seeded grass range on intermediate mountain elevations. This observed preference contrasts with observations from studies on lower ranges, which show that deer feed heavily on grass in early spring. Pellet group studies on Diamond Mountain cattle allotment, Ashley National Forest, show the following rates of annual days' use per acre in aspen and browse types and a seeded mixture of smooth brome and crested wheatgrass:

	Aspen	Browse	Seeded grass
Deer	8.40	5.5	0.07
Elk	5.13	4.5	.07

This evidence suggests that deer and elk apparently did little more than walk through the area.

Similar animal use was observed on seeded grass range at Horn Mountain on the Manti-LaSal National Forest, where no difference in grass utilization could be detected between caged and uncaged plots after deer and elk had been on the area in winter and early spring. Pellet counts on the seeded range indicated only 5 elk days' and 7 deer days' use per acre.

Seeded areas on Diamond and Horn Mountains are located at approximately 8,000 feet elevation. Deer do not reach these areas until May, and their diet then is chiefly forbs. Elk also feed heavily on forbs at this season. When cattle reach the grass-seeded areas in June they prefer the grass forage to the forbs and browse found on adjacent native ranges. Therefore, grass seedings tend to reduce competition between livestock and big game by providing excellent cattle forage.

Developing Big Game Forage

In Utah we are studying ways to increase big game forage on foothill and mountain ranges. A combination of burning and seeding looks promising for certain mountain-brush areas. Many areas in the mountain-brush zone that formerly were valuable winter and spring game ranges have become overrun by brush thickets that often contain little or no herbaceous understory. The original herbaceous cover probably was lost during periods of destructive grazing and promiscuous burning. Fire resistant species such as Gambel oak, black chokecherry, bitter cherry, and snowbush ceanothus have increased and become so dense on many areas that they are almost impenetrable to game or livestock. Such areas apparently have high potentials for forage improvement for big game and livestock.

Burning, dozing, or chaining to reduce these brush thickets, followed by seeding to suitable aggressive grass and broadleaf herbs such as intermediate wheatgrass, smooth brome, and alfalfa can improve these ranges for both game and livestock. The establishment of an aggressive herbaceous understory after burning greatly increases the grazing capacity, provides soil cover, and retards reinvasion by undesirable shrubs.

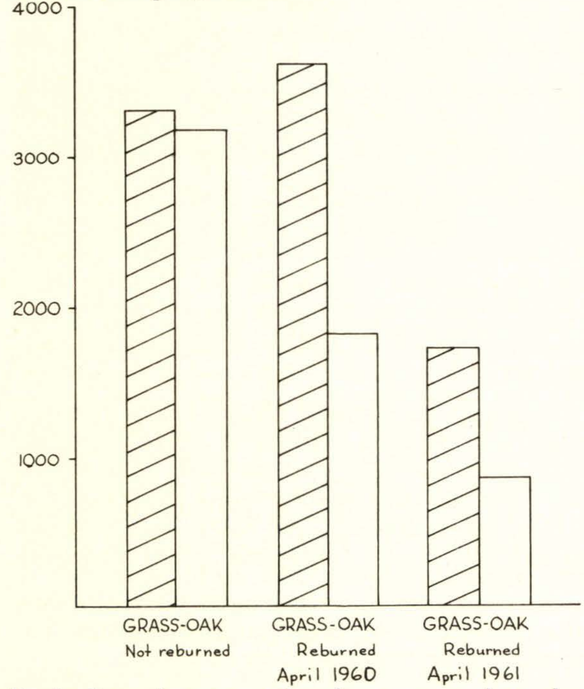
A limited study of burning and seeding in the oak type of the mountain brush zone was made by using the following treatments:

(a) Single burned and seeded in 1955; no further treatment.

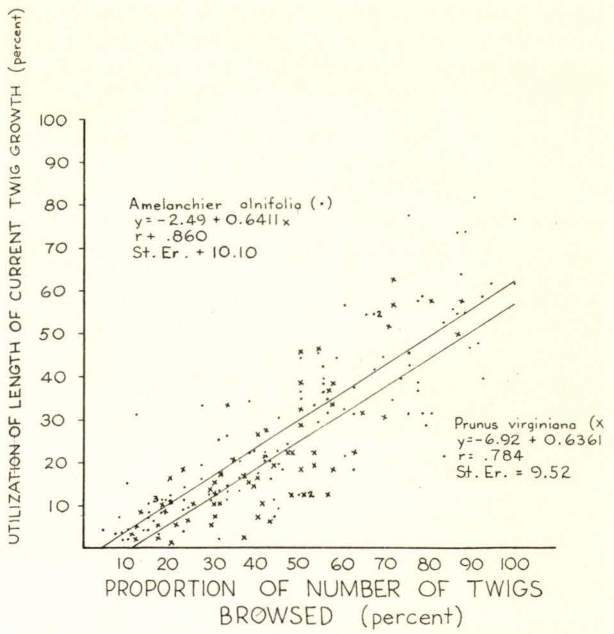
(b) Burned and seeded in 1955; reburned late in April 1960.

(c) Burned and seeded in 1955; reburned late in April 1961.

The amount of grass and oak produced in August 1961 for these three treatments is shown in the following figure.



Production of grass and oak on range burned and seeded in 1955; measured in August 1961.



Regression of utilization of twig length on utilization of twig numbers.

Grass production after the 1955 burning and seeding was still high in 1961 despite the large amount of oak. Reburning retarded both grass and oak growth the first season. But in the second season the production of grass increased to its previous level, while production of oak leaves and twigs was only half that where it was not reburned. Thus, where there is a good understory of fire-resistant herbaceous species such as the intermediate wheatgrass and smooth brome used here, burning offers promise for favoring them over brush such as oak. In this case, burning was done late in April, the beginning of the growing season, when accumulated grass and litter were dry and flammable. Spring fires usually are severe enough to kill the aerial portions of oakbrush, but it resprouts.

We need to study further the beneficial and detrimental potentials of this approach to game and livestock range improvement.

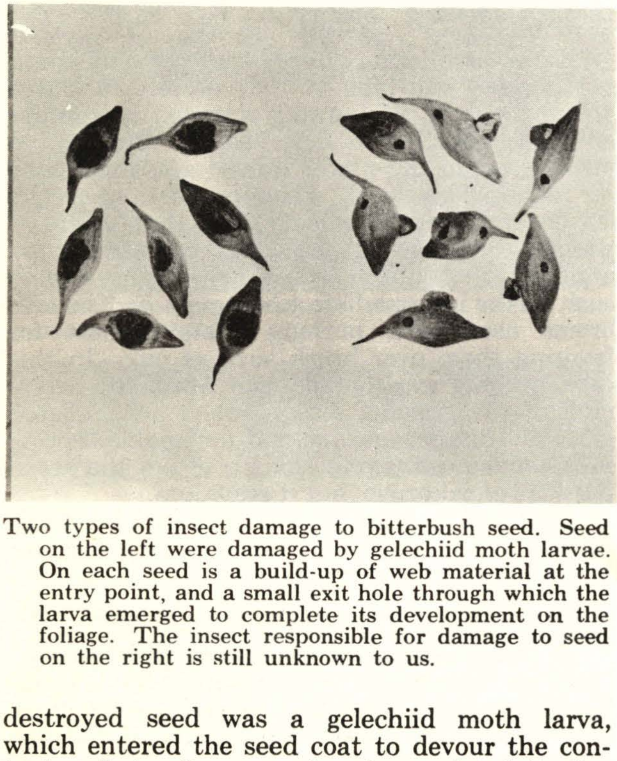
Relation of Insects to Deer Browse

A study of insects associated with regeneration of bitterbrush on southern Idaho winter deer range has shown that several species of insects utilize the flowers and seeds of this important browse plant.

A species of thrips was present in abundance during the early flower stage and destroyed the reproductive portions of many developing flowers.

Several insect species feed on seed that are still attached to shrubs. The adult Says Plant Bug (*Chlorochroa sayi* Stal.) pierced and killed seed with its long beak. These bugs may also have caused a black-colored spotting seen in the accompanying photograph. Germination of the spotted seed was about one-half that of typical unspotted seed. The most unusual insect that destroyed seed was a gelechiid moth larva, which entered the seed coat to devour the contents. Later it emerged and completed its development on the foliage.

Inspection of tagged bitterbrush seed to detect damage by insects. Seed that later dropped into the trap below were examined periodically for damage by insects after seedfall.



Two types of insect damage to bitterbush seed. Seed on the left were damaged by gelechiid moth larvae. On each seed is a build-up of web material at the entry point, and a small exit hole through which the larva emerged to complete its development on the foliage. The insect responsible for damage to seed on the right is still unknown to us.

Causes of other types of seed damage and the relations of many other insects found associated with bitterbrush were not determined. Since insects are suspected of inhibiting bitterbrush regeneration, we are developing studies to determine the relation of insects to germination and development of bitterbrush seedlings, and also to growth and reproduction of other game forage species.

Estimating Browse Utilization by Deer

Wildlife technicians commonly measure current year's twigs before and after deer grazing and express utilization in percent of twig length removed. In Idaho we are investigating some of the fundamental relations of twig diameters, lengths, and weights in an attempt to provide a means of determining utilization solely by post-grazing measurements; also to permit an expression of browse utilization in terms of both weight and twig length. We hope these relations also may be used for estimating productivity of browse species.

Preliminary analyses of data are encouraging and indicate correlation coefficients for the various relations as high as 0.96. Analyses are in process to determine whether any differences exist in regression equations for twig measurements from different parts of shrubs and from different sites.

In western Montana we studied two key browse species, serviceberry (*Amelanchier alnifolia*) and chokecherry (*Prunus virginiana*), on big game winter ranges to determine whether counts of the number of twigs eaten could be used as a basis for estimating amount of utilization. In this study, we defined utilization as the proportion of the total length of current annual growth (measured in centimeters) removed by deer. Twig length measurements were made in the fall before grazing and again in the spring after grazing on 113 serviceberry and 68 chokecherry shrubs. Browse utilization expressed as percent reduction in twig length was compared to the percent of the total number of twigs that were nibbled or grazed by deer.

Measuring bitterbush twig diameters (to 0.001 inch) with a dial gauge—one step in determining diameter-length weight relations in a search for improved methods of estimating browse production and utilization.

The correlations illustrated in the graph accounted for 74 percent of the variation in utilization of current twig growth for serviceberry and 61 percent for chokecherry. This relationship indicates that twig counts in the spring should provide reasonable estimates of average utilization of these two important big game browse species. Percent of twigs browsed can be converted to an estimate of percent of twig length grazed by using the chart or the formulae.

Comparison of Methods of Sampling Sagebrush-Grass Vegetation

In 1960 we tried the angle-order method of sampling vegetation on sagebrush-grass range at the U.S. Sheep Station Experimental Range. It was developed as a means of estimating plant density (number of plants per unit area), but it also offers promise for estimating ground cover and herbage production for many species. This technique requires measurement of distances to plants of a particular species in each of four quadrants around randomly located sample points. Besides measuring distance, estimated green weight (later converted to dry weight) and crown diameter (of shrubs) or basal diameter (of grasses and forbs) were recorded for the individual plants sampled by this method. Densities of the different species were computed from the distance measurements by using formulas developed by Morisita, a Japanese ecologist. Estimated number of plants per acre multiplied by average dry weight per plant gives an estimate of herbage production; or, multiplied by average plant size, provides an estimate of ground cover. These values can be computed for each species.

Estimates of plant density and herbage yields obtained by the angle-order method are compared with plant counts and weight estimates made on 9.6- and 96.0-square-foot plots in the tabulation below. The angle-order method was satisfactory for species in which individual plants could be distinguished easily, such as arrowhead balsamroot (*Balsamorhiza sagittata*), threetip sagebrush (*Artemisia tripartita*), and other shrubs. But for mat-forming shrubs such as hoary phlox (*Phlox canescens*), and bunchgrasses such as bluebunch wheatgrass (*Agropyron spicatum*), it was less satisfactory because individual plants were difficult to distinguish consistently. For example bluebunch wheatgrass plants were found in various stages of disintegration. Such bunches were breaking into smaller bunches and could be counted as 1, 2, or as many as 10 or more indvdiuals, depending on how much probing was done to determine the separate units.

	Bearded bluebunch wheatgrass	Arrowleaf balsamroot	Threetip sagebrush
Estimated plant numbers (density) per acre:			
By angle-order method	38,930	7,690	8,020
By counts on 9.6 sq.-ft. plots	32,520	7,410	7,410
By counts on 96 sq.-ft. plots	17,740	6,080	5,720
Estimated herbage production per acre (lbs.):			
By angle-order method	381	144	148
By estimate on 9.6 sq.-ft. plots	161	131	106
By estimate on 96 sq. ft. plots	121	119	110

Estimates of herbage production computed by the angle-order method generally were higher than those obtained by the weight estimates, especially for bluebunch wheatgrass. For balsamroot and sagebrush, yields obtained by the angle-order method were much nearer those obtained by ocular estimates.

Estimated percent of ground cover obtained by the angle-order method was usually close to that obtained by the line intercept for most species and groups (see following tabulation). The greatest discrepancy was for the group of shrubs other than threetip sagebrush. This group contained several shrubs for which sampling error was high because of inadequate representation of the various species.

	Ground cover estimate[1]	
Species	Angle-order method	Line intercept method
	- - - *Percent* - - -	
Bearded bluebunch wheatgrass	3.6	2.2
Arrowleaf balsamroot	1.1	.5
Threetip sagebrush	12.2	9.7
All other grasses	1.7	1.9
All other forbs	2.1	2.5
All other shrubs	11.5	6.6
Total	32.2	23.4

[1] Basal cover for grasses and forbs; crown cover for shrubs.

In 1961 we tried a combination of methods for sampling the sagebrush-grass vegetation at the Sheep Station. Density, production, and ground cover of balsamroot, sagebrush, anad other shrubs were estimated by the angle-order technique; for grasses and forbs other than balsamroot, production was obtained by clipping 9.6-square-foot plots. Preliminary analysis indicates that this procedure may be quite satisfactory.

WATERSHED MANAGEMENT RESEARCH

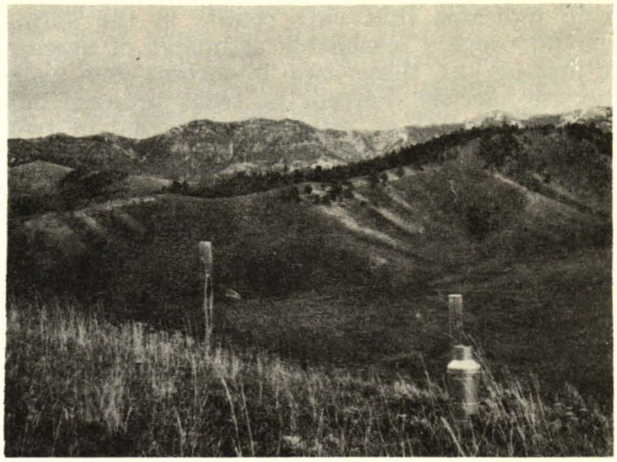
During the past year we have realigned and strengthened the program of watershed management research. All watershed research is now oriented to broad scale problems through the establishment of six major projects having station-territory scope. We have broadened research in water yield improvement and damage prevention methods. Research in watershed rehabilitation continues, and results from several studies in this program form the basis of this report.

Maintenance of soil stability is fundamental to the proper productive and hydrologic functioning of watersheds. This is emphasized repeatedly by the need for regulated maximum yields of usable water, particularly in drought periods, and the control of erratic overland flow flood surges following severe rainstorms. Both these conditions were accentuated during the past year. Prompted by widespread water shortages, advocates of conversion, reduction, or destruction of vegetation to increase water yields became more vocal than usual. Additionally, a severe fire season accounted for destruction of vegetation on thousands of acres; that, in turn, created potentially serious flood threats.

Whether vegetation, an important key to soil stability, is damaged or destroyed intentionally or accidentally matters but little: the result is the unraveling of soil stability. Our report this year presents results that indicate definite requirements for maintaining soil stability, that show the interrelations between numerous watershed factors, and finally, that demonstrate the consequences of exposing bare soil to the impact of storms for a long period.

SOIL STABILITY REQUIREMENTS FOR GRASS-FORB ELK WINTER RANGE

Grass-forb vegetated slopes of the upper Gallatin River valley in Montana are the winter range for large numbers of elk that summer in the Yellowstone National Park and adjacent national forests. Elk use of this winter range is restricted largely to south-facing slopes and ridges bared of snow by melting and wind (See photo). Excessive use has so deteriorated the ground cover and compacted the soil on many of these sites that soil erosion is now greatly accelerated during high-intensity summer rainstorms.


Severely grazed and trampled south-facing slopes of the Gallatin elk range.

A recently complete study on this range reveals information regarding the effects of ground cover, soil bulk density, and summer rainstorm intensity on erosion of an intermediate-textured soil derived from mixed sandstone and shale parent materials. In 1956, ten 1/50-acre plots were established and instrumented to measure amounts of eroded soil. Four plots were protected from further elk use by fencing; of these, two were rehabilitated by reseeding but the other two were not. The remaining six plots were unprotected; and two were reseeded and two were kept untreated. The other two plots were surrounded by snowdrifts so deep during the winter and early spring that they were virtually inaccessible to elk. They supported an excellent native plant cover approaching pristine conditions. This combination of protection, rehabilitation, and circumstantial location provided a wide variety of conditions of cover and soil bulk density on the ten study plots.

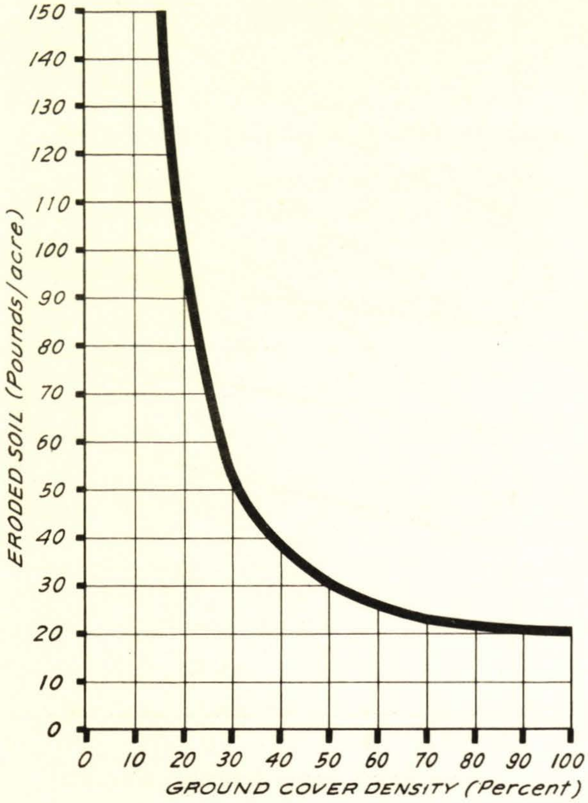
We measured the density of ground cover, the bulk density of the surface 2 inches of the soil mantle, and the weight of soil eroded by four summer rainstorms having maximum 5-minute intensities ranging from 0.80 inch to 1.50 inches per hour. Multiple regression analyses of field data established the following relations:

1. *Ground cover to erosion.*—The amount of soil eroded in relation to density of ground cover at mean soil bulk density (1.14) and mean maximum 5-minute rainfall intensity (1.125 inches per hour) is shown in the first graph on page 37. Under these specifice conditions the smallest amount of eroded soil—about 21 pounds per acre—can be expected from sites where the ground cover is 100 percent. Almost as little soil is likely to be eroded from sites where ground cover is as low as 70 percent, but as the density of cover falls below 70 percent, the amount of eroded soil increases at a rapidly accelerating rate. *A ground cover of about 70 percent, therefore, appears to be one requirement for preventing accelerated erosion on these elk range sites.*

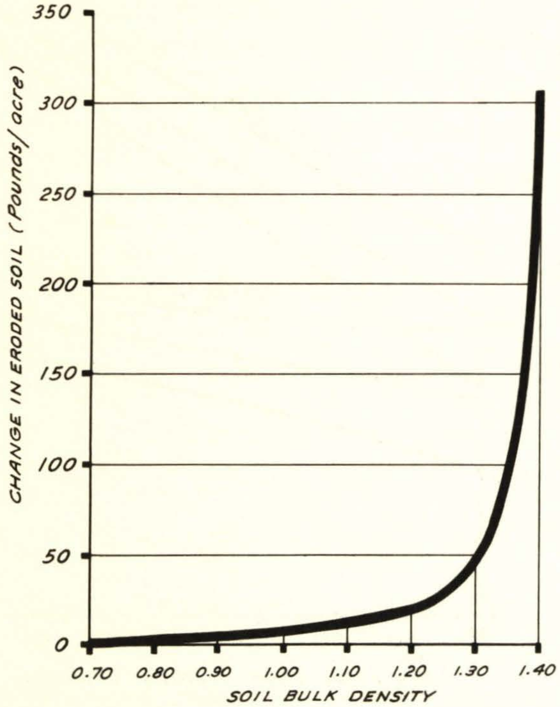
2. *Bulk density to erosion.*—An increase in soil bulk density and, hence, reduction in the infiltration capacity, increased the amount of eroded soil irrespective of the density of the ground cover, as shown in the second graph, page 37. The amount of soil eroded increased quite

slowly as bulk density increased further. *It is reasonable to conclude that, in addition to a minimum ground cover of about 70 percent density, a soil bulk density of 1.10 or less is a requirement for maintaining stablility on the Gallatin elk winter range.*

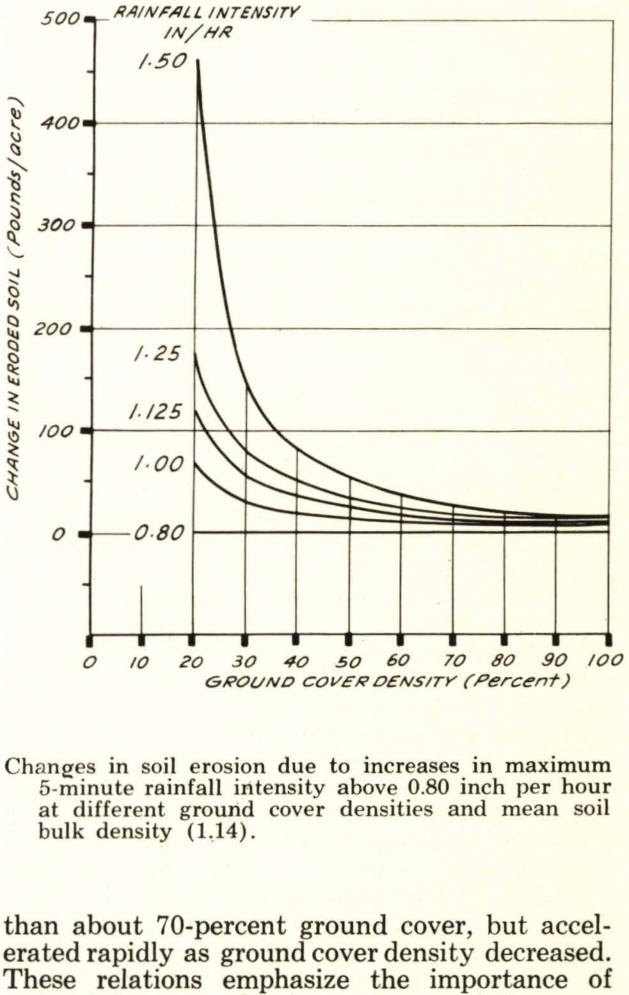
3. *Rainfall to erosion.*—The effect of increases in the maximum 5-minute rainfall intensity above 0.80 inch per hour on soil erosion is shown in the graph below. As rainfall intensity increased, so did soil erosion under all densities of ground cover. Increases in erosion were relatively small on sites having more than about 70-percent ground cover, but accelerated rapidly as ground cover density decreased. These relations emphasize the importance of maintaining enough plant cover and litter on the ground to protect the soil surface against the detaching effect of raindrop impact and the transporting effect of overland flow. Summer storms having high-intensity rainfall bursts ex-



Relation of soil erosion to ground cover density at a mean soil bulk density of 1.14 and a mean maximum 5-minute rainfall intensity of 1.125 inches per hour.



Average changes in soil erosion at mean maximum 5-minute rainfall intensity (1.125 inches per hour) due to increases in soil bulk density above a value of 0.70.



Changes in soil erosion due to increases in maximum 5-minute rainfall intensity above 0.80 inch per hour at different ground cover densities and mean soil bulk density (1.14).

ceeding those measured in this study probably occur every few years on the Gallatin elk range. Under more intense storms, the amounts of soil eroded will likely increase substantially on sites that have poor ground cover but only slightly on well covered sites. *It is reasonable to conclude that, irrespective of the rainfall intensities that might occur, the ground cover and bulk density characteristics that provide soil stability are not likely to depart materially from those stated here.*

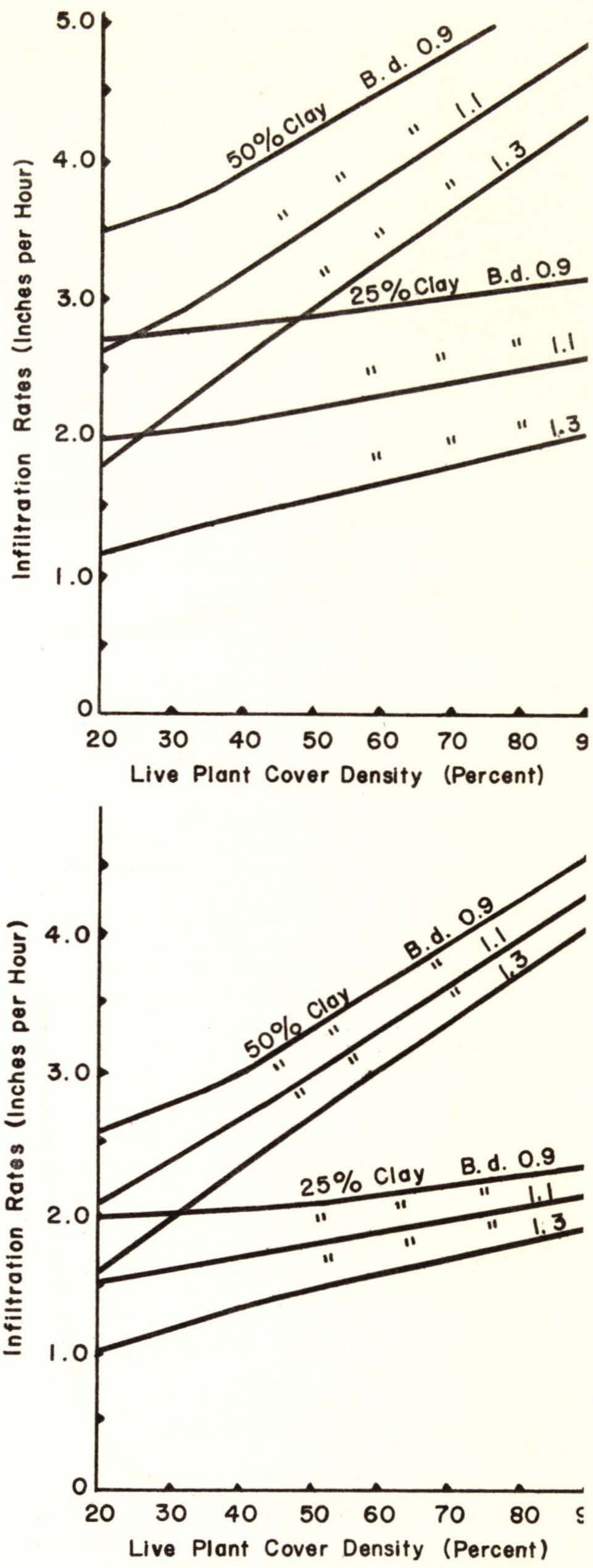
WHAT FACTORS INFLUENCE INFILTRATION AND EROSION?

Studies of infiltration and erosion in central Utah have been expanded to determine the manner and degree in which about 40 different site factors or site-factor interactions are related to these two phenomena. We collected data in 1961 on 164 plots that represented a wide variety of topographic, soil, and vegetal characteristics on summer range land. Graph A, opposite, shows some of the relations determined early in this program. The curves show how infiltration rates, during a 30-minute simulated rainstorm, are influenced by live plant cover, plant litter, bulk density, and clay content of the surface inch of soil. Slope gradient also affects infiltration but, for this analysis, it was held constant at 20 percent. Infiltration was found to decrease about 0.02 inch per hour for each 1-percent increase in slope gradient.

Curves in graph B, opposite, show the infiltration rate that may be expected under given soil and cover conditions and also how this rate will change even if only one factor is modified. For example, reducing plant cover on a soil containing 50 percent clay decreases infiltration rate more than a similar reduction of cover on a soil having only 25 percent clay.

Clay contents of the soils studied ranged from 17 to 54 percent, and within this range, infiltration was generally greater on those soils having most clay. Plant cover enhances the development of soil structure, and the maintenance of dense plant cover on clay soils is a prime requisite for their stability. Live plant cover influences infiltration less on soils low in clay; achieving maximum infiltration requires management that promotes a combination of low bulk density and dense ground cover. To illustrate, in a soil having 25 percent clay and a high bulk density infiltration is low regardless of other factors. Even when bulk density is low, dense litter cover is required for adequate infiltration.

Many other factors significantly influence infiltration and erosion processes. But these two



Infiltration rates of soils during 30-minute simulated rain as influenced by live plant cover density, weight of litter, bulk density, and clay content of surface soil. *A.* 200 pounds of litter per acre; *B.* 2,000 pounds of litter per acre.

investigations in Montana and Utah emphasize that proper management and protection of range-watersheds require knowledge and understanding of the properties of the soils.

INFILTRATION STUDIES ON FROZEN AND SNOW-COVERED GROUND

An exploratory study, believed to be the first of its kind, was completed in 1961 on an east Sierra Nevada watershed as part of a program to study the hydrologic processes involved when a shallow snowpack, frozen soil, and forest vegetation are exposed to prolonged winter rain—a situation that causes floods in the Truckee River Basin.

Prolonged low-intensity rainfall was simulated on small runoff plots that included a wide range of forest floor conditions either inherent in the site or created by extremes of weather, or both. The cobbly sandy loam soil was derived from andesite. Simulated storms were applied for 10 hours in September 1960; they were repeated for 19 hours in December 1960 and March 1961.

Our experiments under these conditions provided data from which we derived an equation for determining the minimum infiltration capacity. This predicted value can be highly useful in a flood analysis; it can be used indirectly to determine on-site overland flow if the storm rainfall rate is known. In field application, the equation can be solved by utilizing previously acquired knowledge of a forest floor condition. We can express the relation of the minimum infiltration capacity (I_m), in inches per hour, to such characteristics as forest floor cover (V_e), in percent, to the absence or presence of contour furrows (C_f), to type of soil frost [$F_{s(b)}$], and to season of year (S_e) thus:

$$I_m = 0.707 + 0.00423V_e + 0.321C_f - 0.166F_{s(b)} - 0.091S_e$$

In developing the equation, minimum infiltration capacity correlated highly with forest ground cover in a positive manner and the area of exposed rock in a negative manner. However, because forest floor cover proved mathematically to be slightly more sensitive for estimating minimum water-intake, it alone is included in the equation.

Inclusion of such nonquantifiable variables as contour furrows, soil frost type, and season of year in the equation, requires substitution of the following analytical equivalents:

Contour furrows

	Yes	No
C_f	+1.0	−1.0

Type of soil frost

	None	Stalactite	Porous-concrete	Concrete
$F_{s(a)}$	−3.0	+1.0	+1.0	+1.0
$F_{s(b)}$	0.0	−2.0	+1.0	+1.0

Season of year

	Summer	Winter
S_e	+1.0	−1.0

The positive sign of the regression coefficient for furrows indicates that shallow furrows spaced close together increase the minimum infiltration capacity 0.32 inch per hour, a rate exceeding normal rainfall during a winter flood. Actually, this amount of improvement is conservative because it is based upon overland flow that originated on the lower furrow berm. Under field practices, the next furrow downslope would trap overland flow from the berm upslope.

This equation also indicates that when a forest floor contains the absorbent, stalactite form of soil frost, it absorbs water 0.33 inch per hour faster than if frost were not present. Should the frost be porous-concrete, the intake of water is slower than if frost were not present. Normally, the amount of this decrease in infiltration capacity is insufficient to cause overland flow. However, if the latter frost condition prevails on a severely deteriorated or burned-over forest, infiltration may be reduced to an amount less than known winter rainfall rates, and overland flow can result.

Our observations showed that dissimilar frost conditions usually occur beneath a shallow snowpack undergoing metamorphic change. For instance, stalactite frost forms on a clear cold night if the surface soil remains moist from the melting of snow during the day. Frost of the porous-concrete type forms in a dryer soil that may exist either under a snowpack too cold to melt or where the shallow snow has recently disappeared. Thus, the same forest floor over a period of a few days may either absorb or shed water quite readily in the event of a rainstorm.

We developed the following equation to ascertain the amount of eroded soil that accompanies overland flow:

$$E_r = 27.373O_f + 2.734R_e - 0.102S_n - 5.018F_{s(a)} - 19.160C_f - 26.003$$

This equation represents the average soil erosion rate (E_r) in tons per square mile per hour, in relation to overland flow rate (O_f) in inches per hour, to exposed rock (R_e) in percent, to the combined area of snow cover before and after a storm (S_n) in percent, to the presence or absence of soil frost [$F_{s(a)}$] and contour furrows (C_f). The significance of such characteristics as overland flow and exposed rock is readily understandable. Overland flow erodes and transports soil detached by raindrop impact, while the presence of exposed rock accelerates the process by reducing infiltration and affording "passageways" that tend to concentrate surface flows. The greater the ground area occupied by exposed rock (up to 23 percent), the greater are soil losses.

The presence of snow cover, soil frost, and contour furrows reduces soil movement. Snow cover absorbs raindrop impact and reduces erosion much as dense vegetation does. Soil frost, before it melts, exerts a strong anti-erosive influence by binding the soil particles and making them more resistant to dislodgment. Shallow contour furrows provide a longer lasting influence by trapping eroded sediment. According to the equation, this trapping of sediment will reduce the predicted soil loss by 19 tons per square mile per hour. This figure is conservative because it is based upon soil eroded from the unprotected furrow berm.

Information of the type gleaned from this project will aid materially our program for studying the influence of land condition on winter floods. We are designing new studies for exploring further the processes involved with winter rain on snow-covered and frozen terrain.

DIFFERENTIAL EROSION OF SOIL PARTICLES

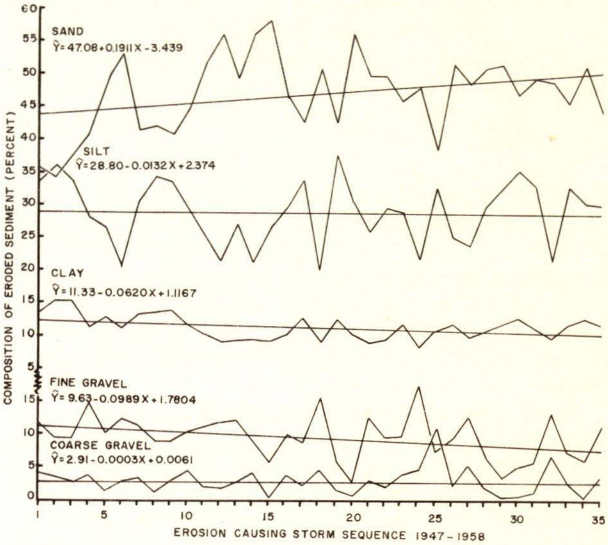
What happens to soil when plant cover is destroyed and erosive processes are unleashed by the continued impact of rainstorms?

Some insight into this problem is afforded by a study of Parrish Plot 7 and the sediment eroded from it during the 12 years following its artificial denudation in 1947. From 1947 through 1958, some 218 summer storms swept over this plot; 40 of them produced overland flow and caused erosion. An average of 18 storms occurred each year, and 3 of them were of sufficient intensity or duration to cause erosion. The average overland flow amounted to 18.8 percent of the rainfall. During this 12-year period, 53.8 tons per acre of soil were eroded by 16,307 cubic feet of overland flow.

This study measured several other significant changes. Compaction of surface soil has increased tremendously—from a bulk density of 0.57 to 1.48. At the same time, porosity has been reduced by 35 percent. Thus the original soil moisture storage capacity of 0.79 inch is now only 0.51 inch. A reduction in permeability also accompanied these changes.

Analyses of soil particles from samples taken from the residual plot surface, an adjacent undisturbed aspen-forested soil, and the eroded sediments that have been retained separately, show physical changes that have occurred.

On the upper two-thirds of the plot a proportionate increase in sand and decrease in silt has occurred, but relatively little change in clay. On the lower one-third of the plot, fine particles tend to accumulate by deposition. A time-trend analysis of the textural composition of sediment eroded from the entire plot by 35 storms over 12 years shows the following trends of soil particle removal from the plot: sand increased, but silt, clay, fine gravel, and soil organic matter decreased; coarse gravel changed but little. Variations in proportionate removal of separates by storm periods is ascribed to variations in storm amount, intensity, and duration (see figure below). Thus, as fine-textured soil particles and soil organic matter continue to be lost, the dynamic seat of soil fertility undergoes further depletion with each storm.



Changes in percentage composition of eroded soil particles by textural classes, Parrish plot 7, 1947-58. Equations represent time-trend changes in erosion of soil separates for 35 storm periods covering 12 years.

Overland flow and the amount of eroded soil are highly correlated (r=+0.886). The mean overland flow per storm period was 466 cubic feet per acre, and mean soil loss was 3,070 pounds per acre. Standard errors of the means are ± 93 and 733, respectively.

Storms capable of producing overland flow and erosion vary in their characteristics. Most of them produced more than one-half inch of rainfall, maximum intensities exceeded 1 inch per hour, and durations were shorter than 2 hours. The amount of erosion was most highly correlated with rainfall intensity.

Prolonged exposure of unprotected steep mountain slopes to the vicissitudes of nature produces undesirable changes in both physical and chemical properties of the soil. When these changes are allowed to proceed unchecked, the eventual task of regaining control of the hydrologic and productive functions becomes increasingly difficult.

PUBLICATIONS

BAILEY, REED W. Challenges in watershed management research. *IN:* Watershed Mangt. Study Conf. Proc., McCall, Idaho, Sept. 11-14; U.S. Forest Service and Univ. Idaho, pp. 7-13. (No reprints)

Watershed management research must provide competent analyses of local and regional watershed problems. This requires recruitment of scientists and adequate financing of research programs.

BAILEY, REED W., and OTIS L. COPELAND. Vegetation and engineering structures in flood and erosion control. Intermountain Forest and Range Expt. Sta., 23 pp., illus. (Processed)

Discusses and illustrates the roles of vegetation and engineering structures in control of overland flow, erosion, and floods. Suggests needed research in watershed management.

BARNES, BURTON V. Hybrid aspens in the Lower Peninsula of Michigan. Rhodora 63(755): 311-324.

Lists and describes aspen hybrids and putative introgressants discovered in the Lower Peninsula of Michigan and discusses the ubiquity of the *Populus grandidentata* X *P. tremuloides* hybrid in southeastern Michigan as compared with its apparent rarity in the northern-most part of Lower Michigan.

BARROWS, J. S. Forest Fire meteorology. Paper presented at NAS-NRC Seminar on Uncontrolled Fires. Cape Cod, Mass., July 18, 1961. (No reprints)

Reviews forest fire meteorology and the relationship of atmospheric factors to fire behavior and control.

BARROWS, J. S. Natural phenomena exhibited by forest fires. Reprint from Publication 786, NAS-NRC, pp. 281-288. (No reprints)

Discusses some characteristics associated with large-scale forest fires and suggests three specific directions for future fire research.

BARROWS, J. S., and (CHARLES C. BUCK)* Forest fire research and the need for fire laboratories. Soc. Amer. Foresters Proc. 1960, pp. 117-120. (No reprints)

Stresses need for laboratory facilities to strengthen an expanded national program of forest fire research.

BINGHAM, R. T. The intraspecies approach in breeding for disease resistance. Recent Advances in Botany, Sec. 14: 1691-1693.

Suggests that with valuable local species the greatest early gains will come from intraspecies breeding. Breeding should be directed toward greater general adaptability in promising introduced species.

BINGHAM, R. T., (A. E. SQUILLACE, and JONATHAN W. WRIGHT). Heritability of resistance in progenies from blister rust-resistant *Pinus monticola* selections. Recent Advances in Botany, Sec. 14: 1606-1612.

Differences between types of mating and between individual single-cross progenies within resistant phenotype X resistant phenotype mating were highly significant. While average control progeny contained 5 percent survivors, the best wind-pollinated progeny of resistant phenotype contained 19 percent survivors, and the best control-pollinated progeny of two resistant phenotypes 48 percent survivors after intense artificial inoculation of F_1 seedlings in tests since 1952.

BRACKEBUSCH, A. P. The significance of Priest River slash research findings to the land manager. West. Forestry and Conserv. Assoc., West. Forest Fire Res. Coun. Proc., pp. 4-6. (No reprints)

Discusses flammability of slash from nine forest species for current year's cutting and after 1 year and 5 years of aging. Reviews the importance of these findings to the land manager.

COLE, WALTER E. The pine butterfly. U.S. Dept. Agr., Forest Serv., Forest Pest Leaflet 66, 4 pp., illus.

Distribution, description, life-history and habits, and control of pine butterfly on ponderosa pine.

COPELAND, OTIS L. Recognition of watershed problems. *IN:* Watershed Mangt. Study Conf. Proc., McCall, Idaho, Sept. 11-14; U.S. Forest Service and Univ. Idaho, pp. 117-126. (No reprints)

Indicates changes in land features that are clues to significant changes in watershed conditions.

COPELAND, OTIS L., Jr. Watershed management and reservoir life. Jour. Amer. Water Works Assoc. 53: 569-578.

Relates watershed conditions to generation of overland flow which in turn leads to erosion and sediment-laden flows. Describes various hydrologic processes on watersheds and shows how sedimentation curtails the useful life of reservoirs.

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CURTIS, JAMES D. Silvicultural limitations of shallow soils. Misc. Pub. 24, 4 pp. (Processed)

Survival and growth of forest trees depend on adequate soil, which provides not only mechanical support but a medium to furnish moisture and nutrients.

CURTIS, JAMES D. Can ponderosa pine in brushfields be sprayed after planting? Research Note 84, 2 pp. (Processed)

The results obtained by hand spraying a Ceanothus brushfield, in which ponderosa pine had been planted, with 2,4,5-T in water suggest that little is to be gained by applying herbicides after planting under the conditions outlined.

CURTIS, JAMES D. Review of "Choice of Tree Species" by Food and Agricultural Organization of the United Nations. Jour. Forestry 59: 524. (No reprints)

CURTIS, JAMES D., and (MELVIN A. COONROD). The Town Creek ponderosa pine plantations.. Soc. Amer. Foresters Proc. 1960, pp. 21-25.

A 5-year planting test in central Idaho of three kinds of ponderosa pine stock outplanted on sites having three kinds of preparation showed that site preparation had the greatest effect on survival and that kinds of stock also had a significant effect.

CURTIS, JAMES D., and MARVIN W. FOILES. Ponderosa pine seed dissemination into group clearcuttings. Jour. Forestry 59: 766-767.

Natural regeneration appears to be an unreliable means of regeneration in the ponderosa pine type in central Idaho, because of the infrequency and unpredictability of heavy seed crops, the ubiquity of small rodents, and the forest manager's inability to cope with them.

DODGE, HAROLD R. Parasitism of spruce budworm by *Glypta* and *Apanteles* at different crown heights in Montana. Canad. Ent. 93: 222-228.

Reports differences in degree of parasitism by two budworm parasites at different levels within crown of Douglas-fir trees in Montana.

DODGE, HAROLD R. Studies on female sarcophagid flies: I. *Sarcophaga aldrichi* Parker, *hinei* Aldrich, *houghi* Aldrich, and *Agria affinis* (Fallen). Canad. Ent. 93: 781-785.

Morphology of genital segment of Sarcophagidae are described, females of four species are keyed, and notes on biologies presented. Three of the species have been reared from lepidopterous forest insects.

FOILES, MARVIN W. Effects of thinning seed spots on growth of three conifers in the Inland Empire. Jour. Forestry 59: 501-503.

Number of seedlings per spot significantly affected diameter growth of 17-year-old ponderosa pine, western white pine, and Engelmann spruce trees. Number per spot also significantly affected height growth of ponderosa and western white pine in one test, but did not significantly affect height growth of western white pine in another test or of Engelmann spruce.

FUQUAY, D. M. Characteristics of Rocky Mountain lightning storms. Paper presented at 187th Natl. Meeting of the American Meteorological Soc., held in conjunction with the Pacific Division of the American Assoc. for the Advancement of Science, June 14-16, 1960. (No reprints)

Statistical data on the regional occurrence of thunderstorms and the density of cloud-to-ground lightning strikes are presented.

FUQUAY, D. M. Some thunderstorm statistics for the Northern Rocky Mountain Region. Paper presented at the conference on the design and conduct of Research Programs in Weather Modification, Big Meadows Lodge, Shenandoah National Park, Va., May 1-3, 1959. (No reprints)

Presents data from a 5-year study of the occurrence and movement of thunderstorms in the Northern Rocky Mountain Region. Records aerial density of lightning strikes and the results of preliminary experiments in lightning modification.

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*Parentheses indicate authors who are not members of the Intermountain Station staff.

(GILBERTSON, R. L.), C. D. LEAPHART, and (F. D. JOHNSON). Field identification of roots of conifers in the Inland Empire. Forest Sci. 7: 352-356.

Supplies a useful key and descriptions of the roots of the 11 most important commercial tree species of nothern Idaho and adjoining areas, which enables workers to identify small pieces of roots or rootlets.

GRAHAM, D. P. Dwarfmistletoe of Douglas-fir. U.S. Dept. Agr., Forest Serv., Forest Pest Leaflet 54, 4 pp., illus.

Briefly describes the parasite and its damage to Douglas-fir; discusses control procedures.

GRAHAM, D. P. Dwarfmistletoe pilot control in lodgepole pine clearcuts. U.S. Dept. Agr., Forest Serv., Intermountain Sta. Evaluation Survey Rpts., 7 pp. (Processed)

Evaluates the biological adequacy of the control in pilot tests, and suggests improvements of control procedures.

GRAHAM, D. P., and (C. D. LEAPHART). Larch and lodgepole pine dwarf-mistletoes attack Scotch pine. Jour. Forestry 59: 375-376, illus.

A 55-year-old planting of Scotch pines in northeastern Washington has become heavily infected and severely damaged by two native dwarfmistletoes. This is the first published record of dwarfmistletoe infection of Scotch pine.

HARTMAN, HOMER L.[1] Antibiotics look good in the fight to save western white pine from blister rust. Soc. Amer. Foresters Proc. 1960, pp. 133-134. (No reprints)

Reports the practical field application and potential of antibiotics in the control of white pine blister rust.

ISRAELSON, MARGUERITE A. Publications: 1956 through 1960. Research Paper 29 (Suppl.), 32 pp. (Processsed)

Lists publications of Intermountain Station for the period indicated.

JULANDER, ODELL, (W. LESLIE ROBINETTE), and (DALE A. JONES). Relation of summer range condition to mule deer herd productivity. Jour. Wildlife Mangt. 25: 54-60.

Reports the deleterious effects of inadequate summer range forage on mule deer herd productivity and urges stocking to insure adequate year-long forage for maximum herd production.

KIDD, W. J., Jr., High-intensity rainstorms on the Boise and Payette National Forests. Research Note 81, 4 pp.

High-intensity storms which exceed the infiltration capacity of the soil may occur from May through September on the Boise and Payette National Forests. Tables show record of high-intensity storms and maximum short-duration rainfall intensities for various locations.

KIMMEY, J. W. Problems and possibilities in deterioration of fire-killed stands in the West. Eighth West. Internatl. Forest Dist. Work Conf. Proc., pp. 22-26. (No reprints)

Defines deterioration and discusses problems it causes in salvage of fire-killed stands, and management in general; suggests a program of research needed to solve these problems.

KIMMEY, J. W., and (H. H. BYNUM, Jr.). Heart rots of red and white firs. U.S. Dept. Agr., Forest Serv., Forest Pest Leaflet 52, 4 pp., illus.

Briefly describes the two types of rot and lists and evaluates importance of the principal fungi that cause them. Discusses location in trees where various fungi cause decay; lists external indicators on trees that indicate cull from heart rots. Suggests methods for reducing future losses from heart rots.

KIMMEY, J. W., and (W. W. WAGENER). Spread of white pine blister rust from ribes to sugar pine in California and Oregon. U.S. Dept. Agr., Tech. Bul. 1251, 71 pp., illus.

A detailed report of 56 field tests, 1935-1950, in sugar pine stands in Oregon and California designed to provide an index of the pattern and distance of spread of this rust from principal ribes hosts. Discusses significance of results in relation to climate and the control of this disease in parts of the range of sugar pine.

LAYCOCK, WILLIAM A. Improve your range by heavy fall grazing. Natl. Wool Grower 51(6): 16, 30, illus.

Discusses the seasonal components of the streamflow hydrograph for Halfway Creek, including base flow, snowmelt peak, and recession. Illustrates the effect of watershed condition on storm peak discharges.

[1]Cooperator

(LEAPHART, C. D.), and R. E. DENTON. Needle discolorations of western larch. U.S. Dept. Agr., Forest Serv., Forest Pest Leaflet 61, 7 pp., illus.

Describes and evaluates relative importance of principal diseases and insects on the foliage of western larch; discusses control possibilities.

LLOYD, M. G. The contribution of dew to the summer water budget of northern Idaho. Amer. Met. Soc. Bul. 42: 572-580, illus.

Presents data on duration and amount of dew deposited under a variety of topographic and vegetative-cover conditions.

MARSTON, RICHARD B. Seasonal meteorological effects upon streamflow in northern Utah. Internatl. Assoc. Sci. Hydrology Bul. VI: 45-52, illus.

Discusses the seasonal components of the streamflow hydrograph for Halfway Creek, including base flow, snowmelt peak, and recession. Illustrates the effect of watershed condition on storm peak discharges.

MARSTON, RICHARD B., and ODELL JULANDER. Plant cover reductions by pocket gophers following experimental removal of aspen from a watershed area in Utah. Jour. Forestry 59: 100-102, illus.

Reports increase in pocket gophers and damage to herbaceous species on an experimental watershed plot converted from aspen to herbaceous type.

MIELKE, J. L. Comandra blister rust. U.S. Dept. Agr., Forest Serv., Forest Pest Leaflet 62, 7 pp., illus.

Briefly discusses distribution and importance of this disease on different hosts; gives life history and description of the disease; suggests methods to reduce damage in managed forest stands.

MIELKE, J. L. Deterioration of insect-killed stands in Rocky Mountain areas. Eighth West. Internatl. Forest Dis. Work Conf. Proc., pp. 30-40. (No reprints)

This discussion of deterioration in insect-killed stands and of the salvage and other problems involved names some fungi that trigger insect attack; suggests forest management measures for control.

MERRIAM, ROBERT A. Surface water storage on annual ryegrass. Jour. Geophys. Res. 66: 1833-1838, illus. (No reprints)

Water was sprinkled on annual ryegrass to estimate the amount that could be held by the plants after cessation of rainfall. The amount was equivalent to a film 0.005-inch thick over the entire vegetative surface of the plant, a value near the equivalent film thickness of other types of vegetation.

MERRIAM, ROBERT A. Author's reply to the preceding discussion. Jour. Geophys. Res. 66: 1955. (No reprints)

Author's brief closure to a discussion of an earlier article, "A Note on the Interception Loss Equation," Jour. Geophys. Res. 65: 3850-3851, illus.

MERRIAM, ROBERT A. Saving water through chemical brush control. Jour. Soil and Water Conserv. 16: 84-85, illus. (No reprints)

A dense stand of brush on deep soil in southern California was killed with 2,4,5-T. Nearly 13 inches of water remained in the soil at the end of a dry summer after spraying, compared to 2 inches at a comparable time of the year, prior to spraying. Daily and seasonal evapotranspiration losses before and after spraying are given.

MOESSNER, KARL E. Comparative usefulness of three parallax measuring instruments in the measurement and interpretation of forest stands. Photogrammetric Eng. 27: 705-709, illus.

The accuracy and efficiency of three simple height-measuring devices are evaluated for forestry use. Records of measurement and elapsed time of five photo interpreters who used these height-finding instruments in measuring forest stands were analyzed in the study.

MOSS, VIRGIL D.[1] Antibiotics for control of blister rust on western white pine. Forest Sci. 7: 380-396, illus.

Reports the discovery, development, and systemic action of the two antifungal antibiotics, cycloheximide and phytoactin, and describes the *in vivo* screening tests of 66 compounds selected from several hundred investigated.

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[1] Cooperator or collaborator

PACKER, PAUL E. The effects of grazing on soil erosion, water quality, and sedimentation. *IN:* Watershed Mangt. Study Conf. Proc., McCall, Idaho, Sept. 11-14; U.S. Forest Service and Univ. Idaho, pp. 133-157. (No reprints)

Shows minimum plant and litter cover required to maintain stability of various types of soil on different degrees of slope.

(SHAW, C. G., and B. D. THYR).[1] Sporadic diseases in young stands of the Inland Empire region. Eighth West. Internatl. Forest Dis. Work Conf. Proc., pp. 11-13. (No reprints)

Points out variation between different foliage diseases in regularity of occurrence; shows how rainfall, other climate variations, and the life cycle of a particular organism together account for sporadic occurrence of diseases.

SHEARER, RAYMOND C. A method of overcoming seed dormancy in subalpine larch. Jour. Forestry 59: 513-514.

Soaking subalpine larch seed, which must be treated to assure germination, in a U.S.P. 3-percent solution of H_2O_2 promoted germination.

SHEARER, RAYMOND C. First-year mortality of coniferous seedlings in the western larch — Douglas-fir type. Montana Acad. Sci. Proc. 20: 18-19. (No reprints)

First-year mortality of western larch, Douglas-fir, Engelmann spruce, and subalpine fir seedlings was studied on north, south, and west aspects and the amount of mortality by cause was measured on watered, weeded, shaded, and nontreated quadrats.

STATION STAFF. Highlights in research: annual report, 1960. (Processed)

Reports year's activities of the Intermountain Station.

STICKNEY, PETER F. Range of rough fescue (*Festuca scabrella* Torr.) in Montana. Montana Acad. Sci. Proc. 20: 12-17.

Describes rough fescue, its range in Montana, and characteristic sites where it is found.

TACKLE, DAVID. Ten-year results of spot seeding and planting lodgepole pine. Research Note 83, 6 pp., illus. (Processed)

Summarizes stocking trends and height and diameter growth. Compares results of seeding with planting 1-1 nursery stock.

TERRELL, TOM T. Estimating defoliation caused by spruce budworm from undamaged shoots. Research Note 86, 2 pp., illus. (Processed)

Presents table for field use in estimating defoliation by budworm. Conversion of data on percentage of undamaged buds in samples to defoliation estimate.

(WAGENER, W. W.) and J. L. MIELKE. A staining-fungus root disease of ponderosa, Jeffrey, and pinyon pines. U.S. Dept. Agr., Agr. Res. Serv., Plant Dis. Rptr. 45: 831-835, illus. (No reprints)

Describes and discusses a root disease that has killed thousands of trees of all ages in California, Colorado, and Arizona. This disease, first reported from Montana by Leaphart in the Intermountain Station's 1960 Annual Report, represents a new type of pathogenic root disease in forest trees.

WICKER, E. F., and (C. D. LEAPHART). Effects of three antibiotics on tree diseases and forest vegetation following aerial application to western white pine stands. U.S. Dept. Agr., Agr. Res. Serv., Plant Dis. Rptr. 45: 722-724. (Processed) (No reprints)

First-year observations indicated that the antifungal antibiotics cycloheximide (Acti-dione) and phytoactin, as used, promoted control only on white pine blister rust. The semicarbazone derivative of cycloheximide appeared to effect some control of *Rhabdocline pseudotsugae.* Phytotoxic responses of forest vegetation other than white pine were minor for all treatments.

WIKSTROM, JOHN H., and CHARLES A. WELLNER. The opportunity to thin and prune in the Northern Rocky Mountain and Intermountain Regions. Research Paper 61, 14 pp., illus. (Processed)

Analyzes the effect of overcrowding and limb persistence on timber volume and value yield, the costs that would be involved in thinning and pruning, and the values that would be produced.

WILSON, ALVIN K. Northern Rocky Mountain pole production shows small gain in 1960. Research Note 85, 4 pp. (Processed)

The annual survey of commercial pole production showed that 1960 output, at 437,162 poles, was 2 percent higher than that of 1959, due largely to nearly counterbalancing changes in the production of western redcedar and lodgepole pine poles.

WILSON, ALVIN K. Montana Christmas tree shipments slump in 1960. Research Note 82, 4 pp., illus. (Processed)

The annual survey provided an estimate of 3.2 million trees shipped in 1960, a figure 15 percent below 1959 exports and the most marked single year's decline since 1947.

The Intermountain Forest and Range Experiment Station, U.S. Forest Service, has headquarters in Ogden, Utah, and offices at:

Boise, Idaho
Bozeman, Montana (in cooperation with Montana State College)
Ephraim, Utah
Logan, Utah (in cooperation with Utah State University)
Missoula, Montana (in cooperation with Montana State University)
Moscow, Idaho (in cooperation with University of Idaho)
Provo, Utah (in cooperation with Brigham Young University)
Reno, Nevada (in cooperation with University of Nevada)
Spokane, Washington

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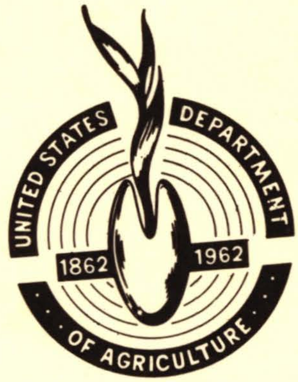
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